

(12) **United States Patent**  
**Britz et al.**

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(54) **METHOD AND APPARATUS FOR MOUNTING NETWORK DEVICES**

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(65) **Prior Publication Data**

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**Related U.S. Application Data**

(63) Continuation of application No. 15/372,472, filed on Dec. 8, 2016, now Pat. No. 10,103,422.

(51) **Int. Cl.**

**H01Q 5/10** (2015.01)  
**H01Q 1/12** (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ..... **H01Q 1/1242** (2013.01); **H01Q 1/1228** (2013.01); **H01Q 5/10** (2015.01); **H01Q 5/22** (2015.01); **H01Q 9/0485** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/1242; H01Q 5/10; H01Q 5/22;  
H01Q 1/1228; H01Q 9/04

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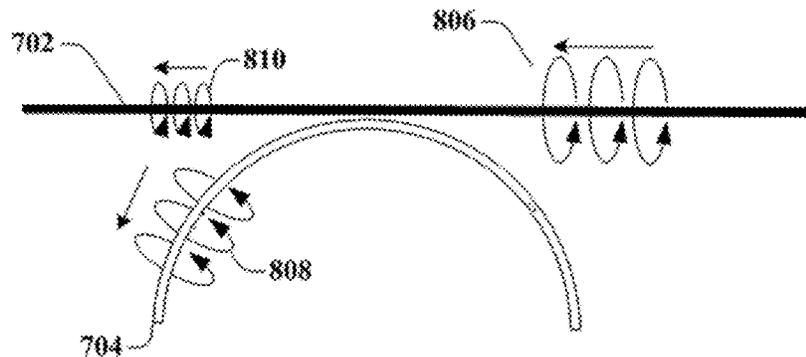
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Matthew Tropper

(57) **ABSTRACT**

Aspects of the subject disclosure may include, for example, an antenna including a dielectric antenna and a mounting carriage connectable with a mounting bracket. Wireless signals can be transmitted by electromagnetic waves that propagate without requiring an electrical return path, where the electromagnetic waves are guided by a dielectric core of a cable coupled to a feed point of the dielectric antenna. The mounting bracket is connectable with a cross member of a utility pole, where the mounting carriage includes an opening for receiving an antenna mount, and where, when received in the mounting carriage, the antenna is suspended beyond distal ends of the cross member. Other embodiments are disclosed.

**20 Claims, 44 Drawing Sheets**



- (51) **Int. Cl.**  
**H01Q 9/04** (2006.01)  
**H01Q 5/22** (2015.01)
- (58) **Field of Classification Search**  
 USPC ..... 343/890  
 See application file for complete search history.

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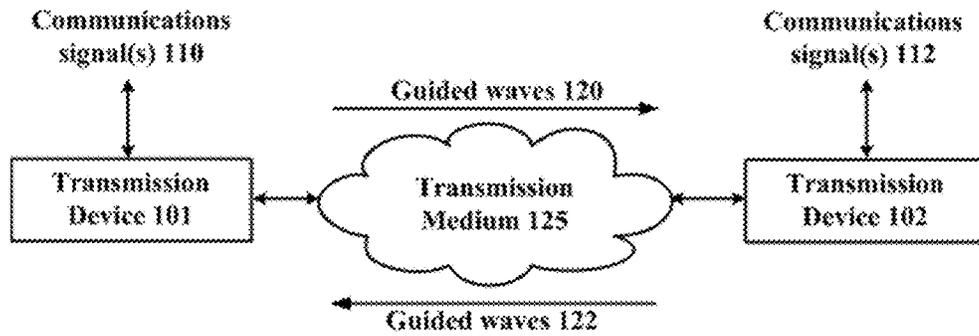
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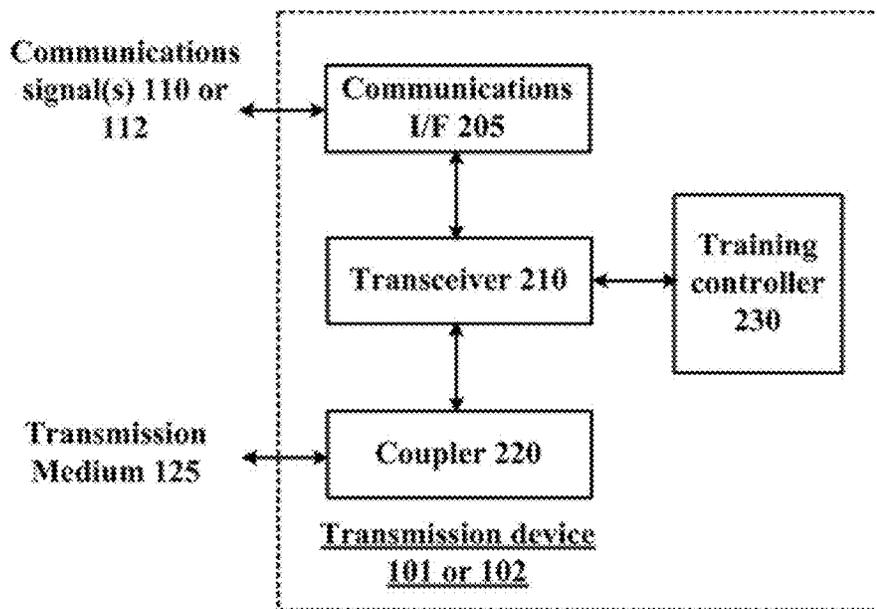
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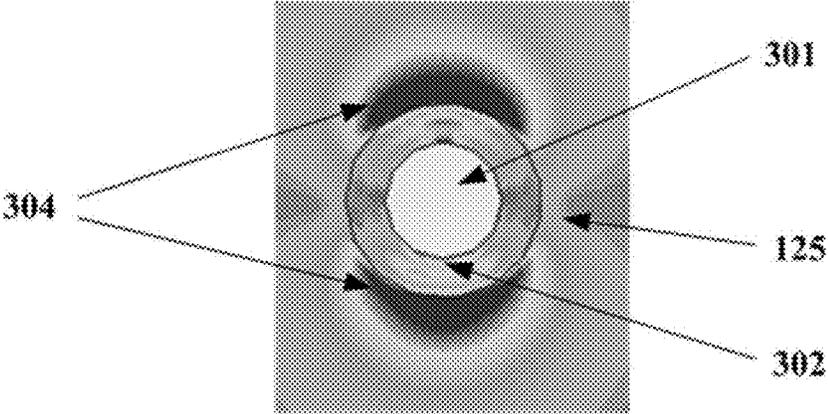
100

FIG. 1

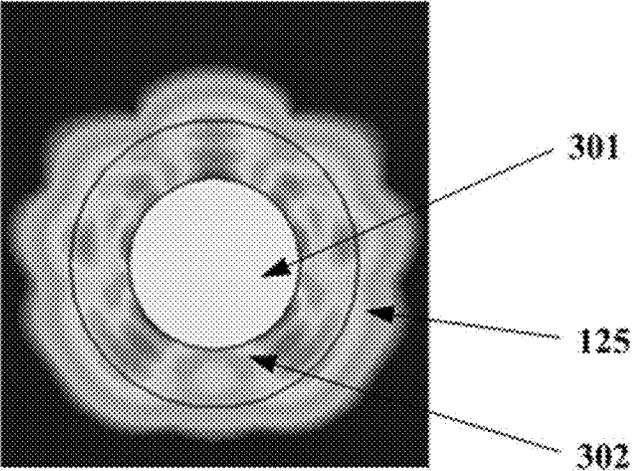


200

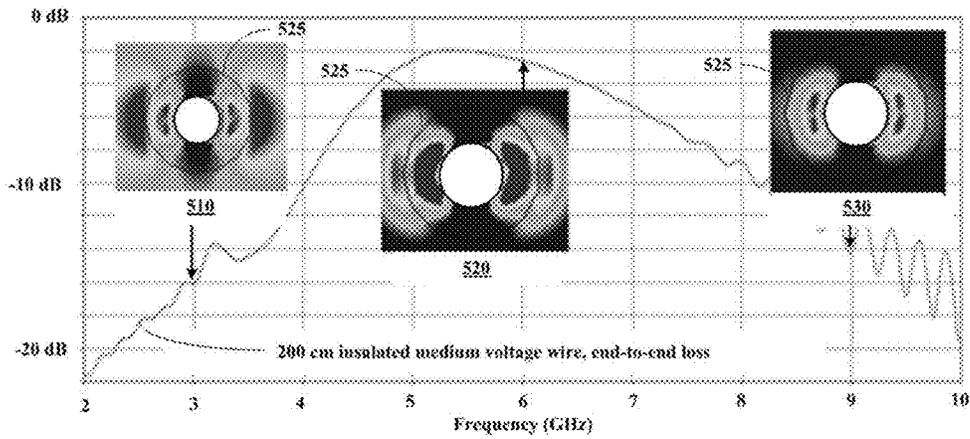
FIG. 2



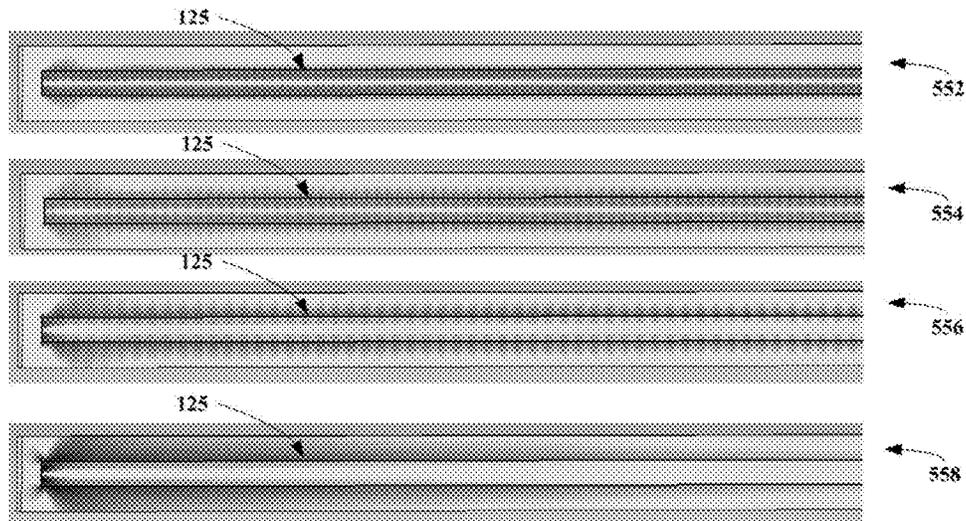
300  
**FIG. 3**



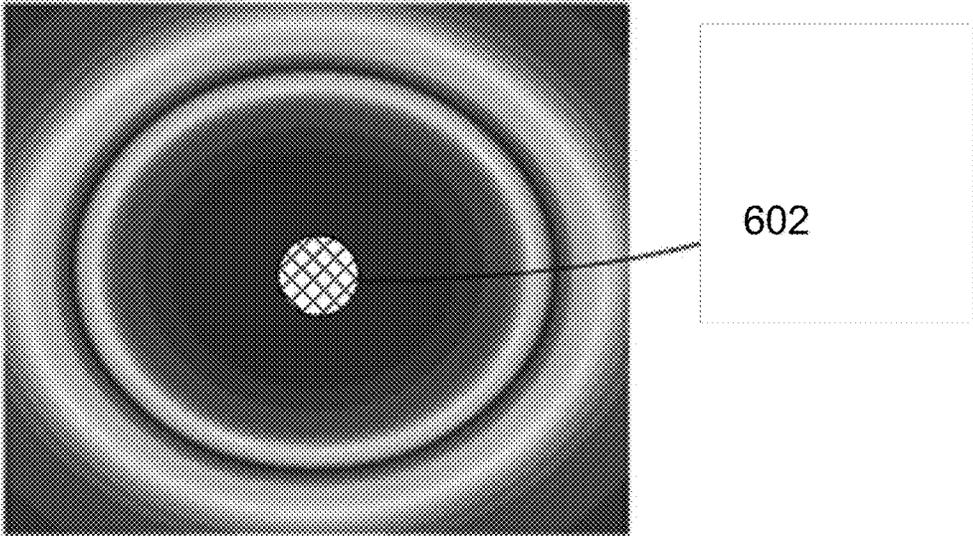
400  
**FIG. 4**



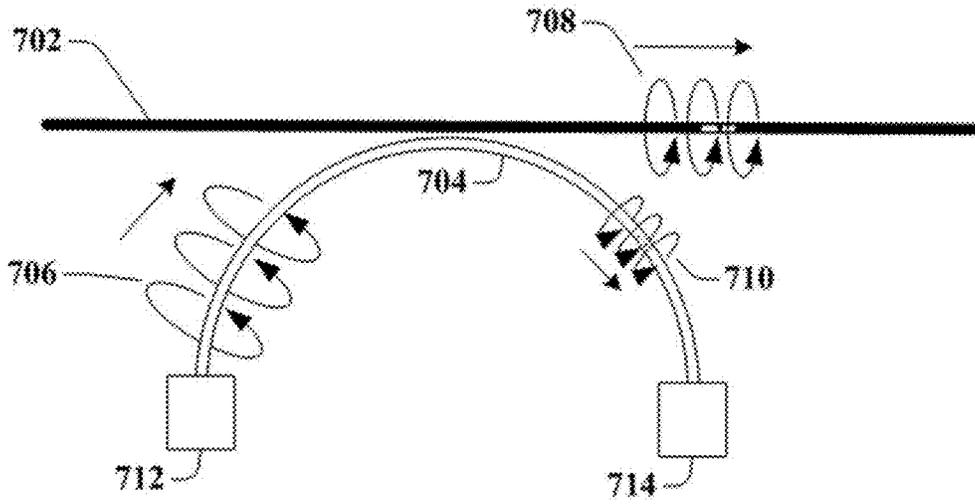
**500**  
**FIG. 5A**



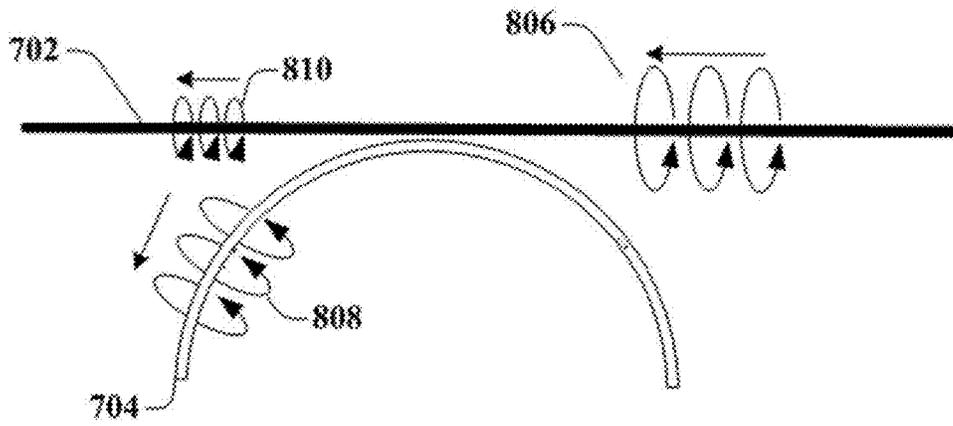
**550**  
**FIG. 5B**



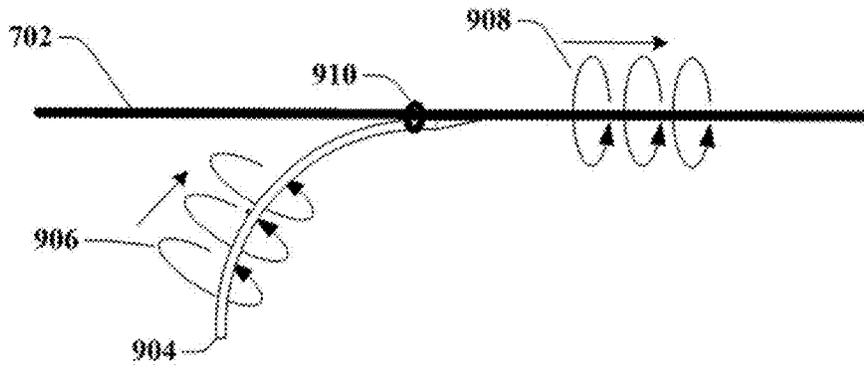
600  
**FIG. 6**



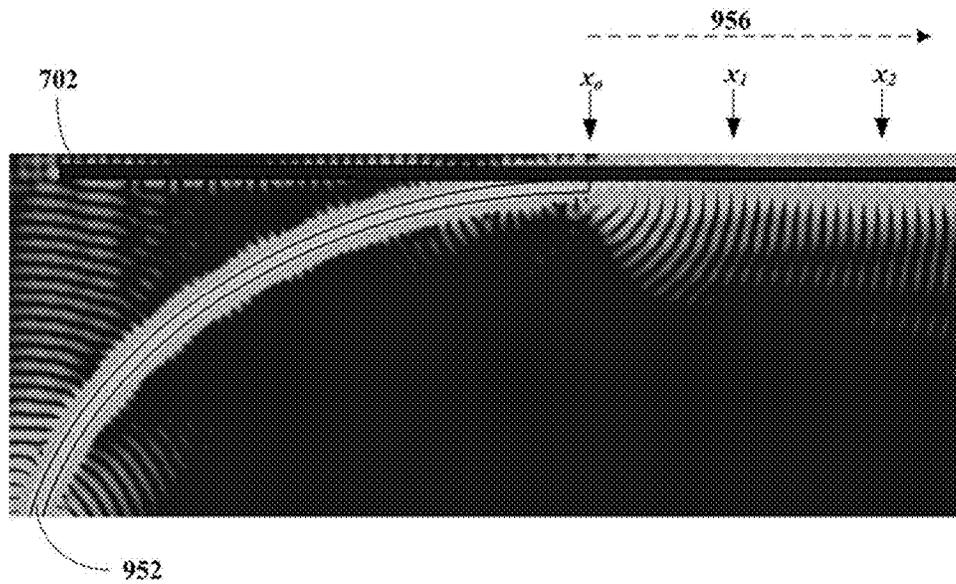
700  
FIG. 7



800  
FIG. 8

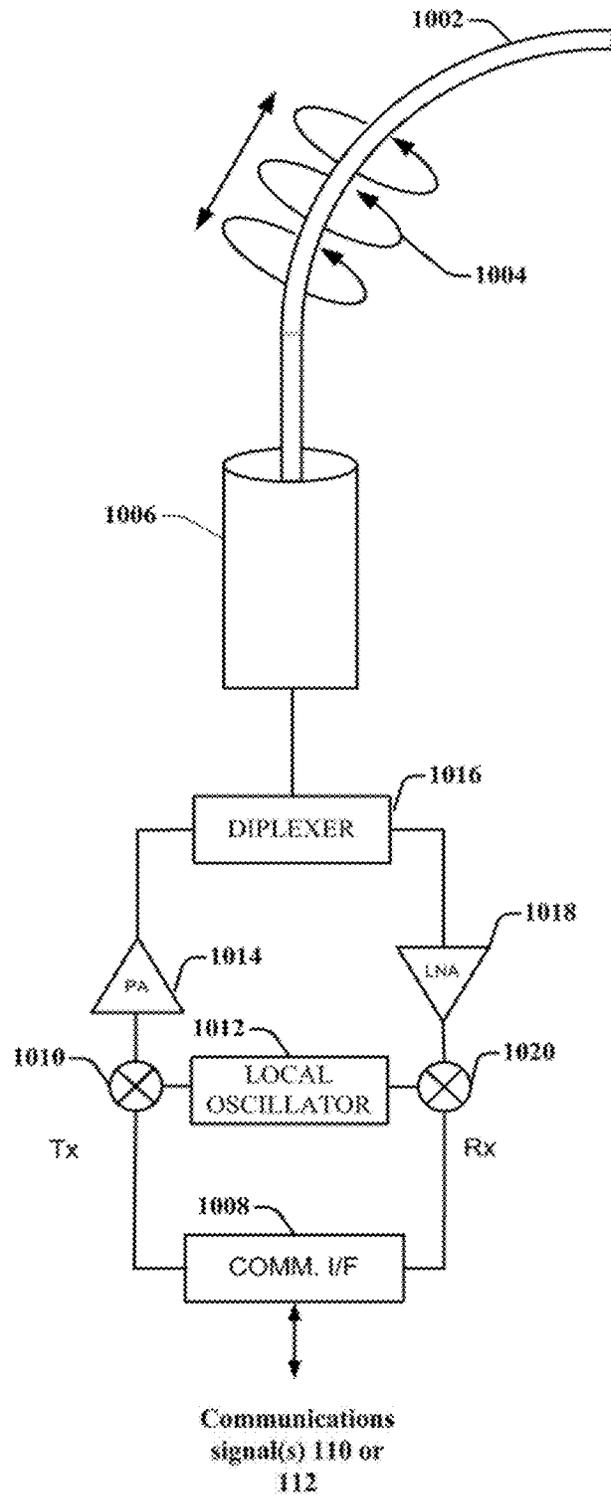


900  
FIG. 9A



950  
FIG. 9B

1000  
FIG. 10A



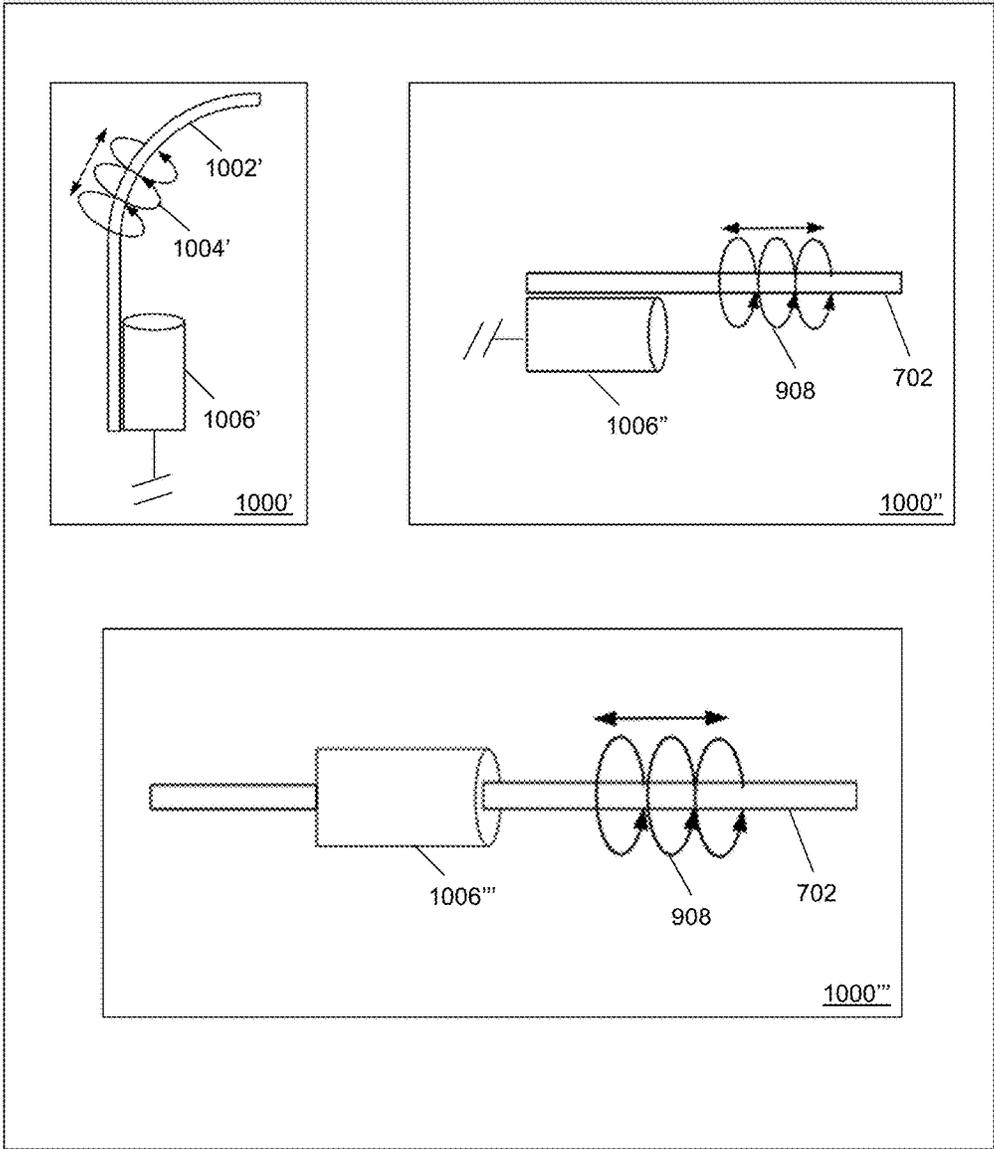
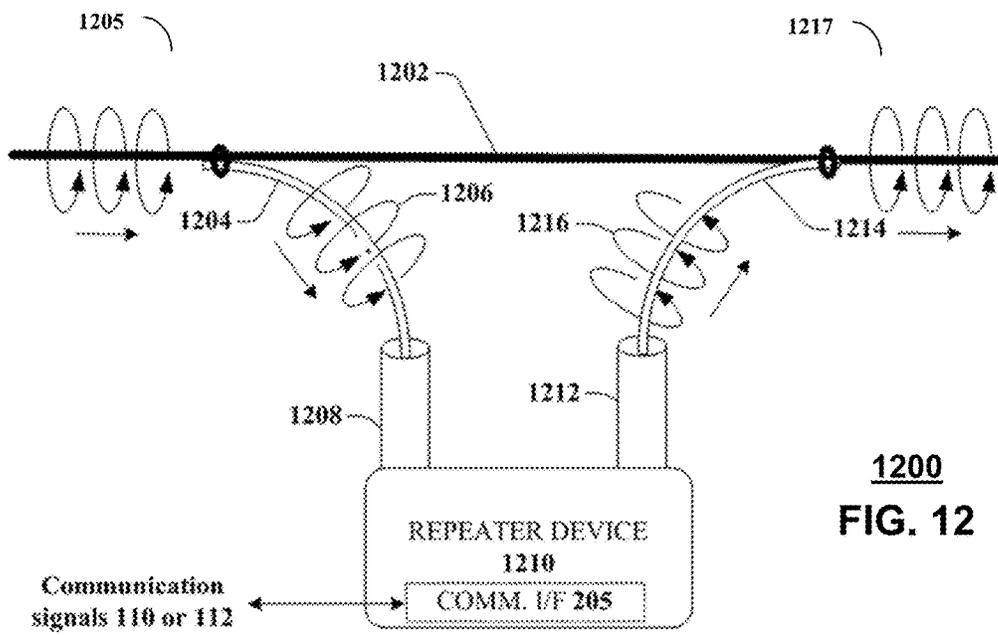
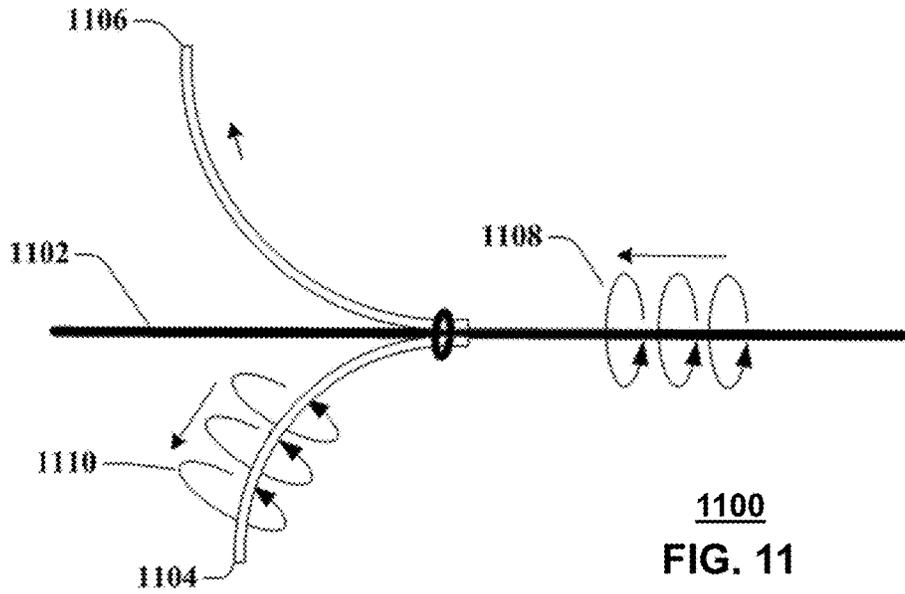
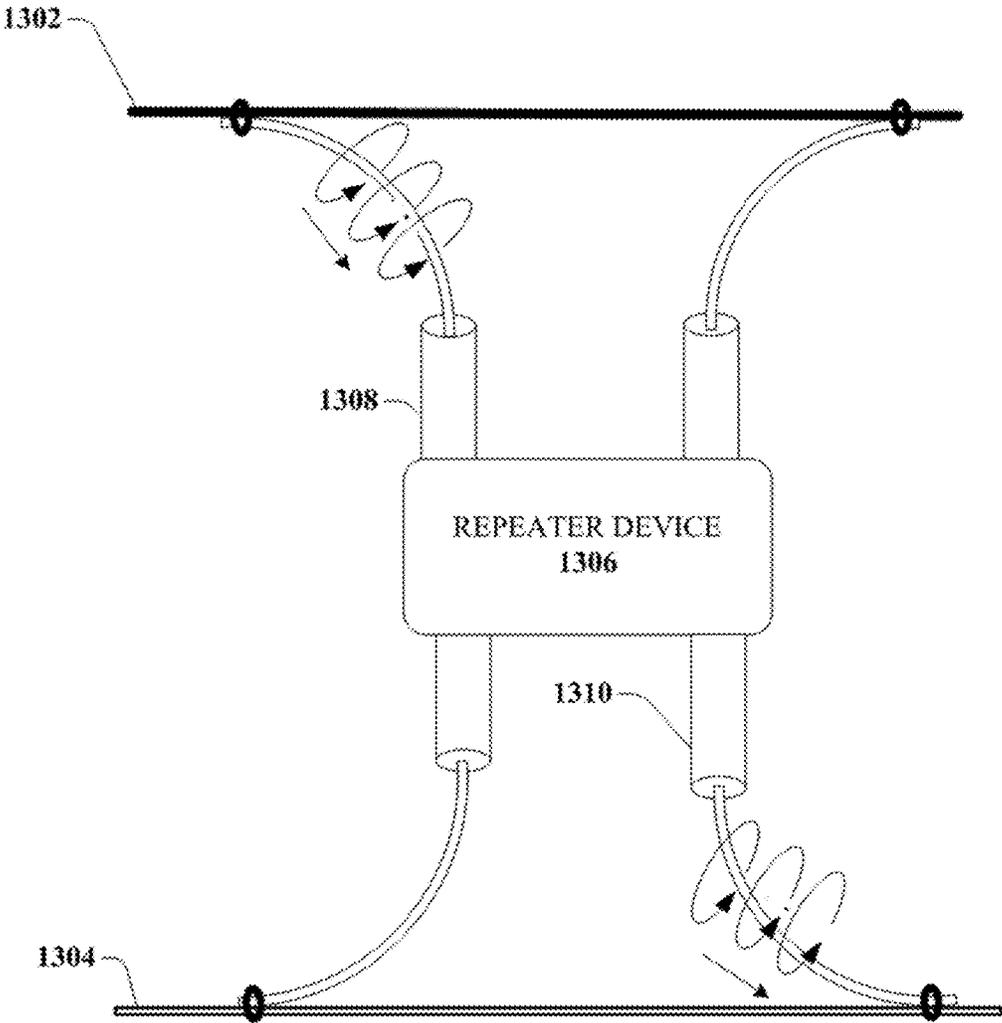


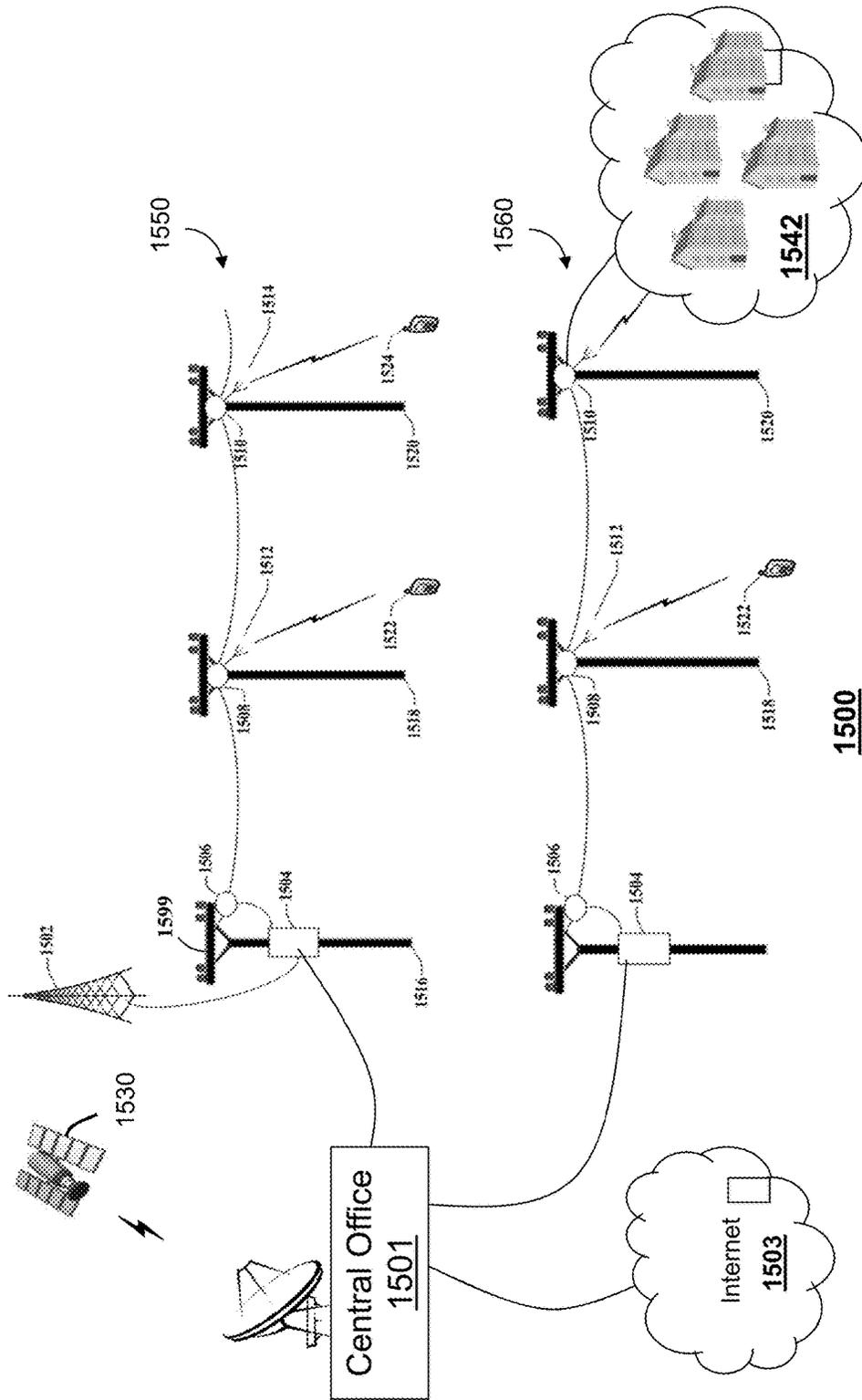
FIG. 10B





1300  
FIG. 13





1500  
**FIG. 15**

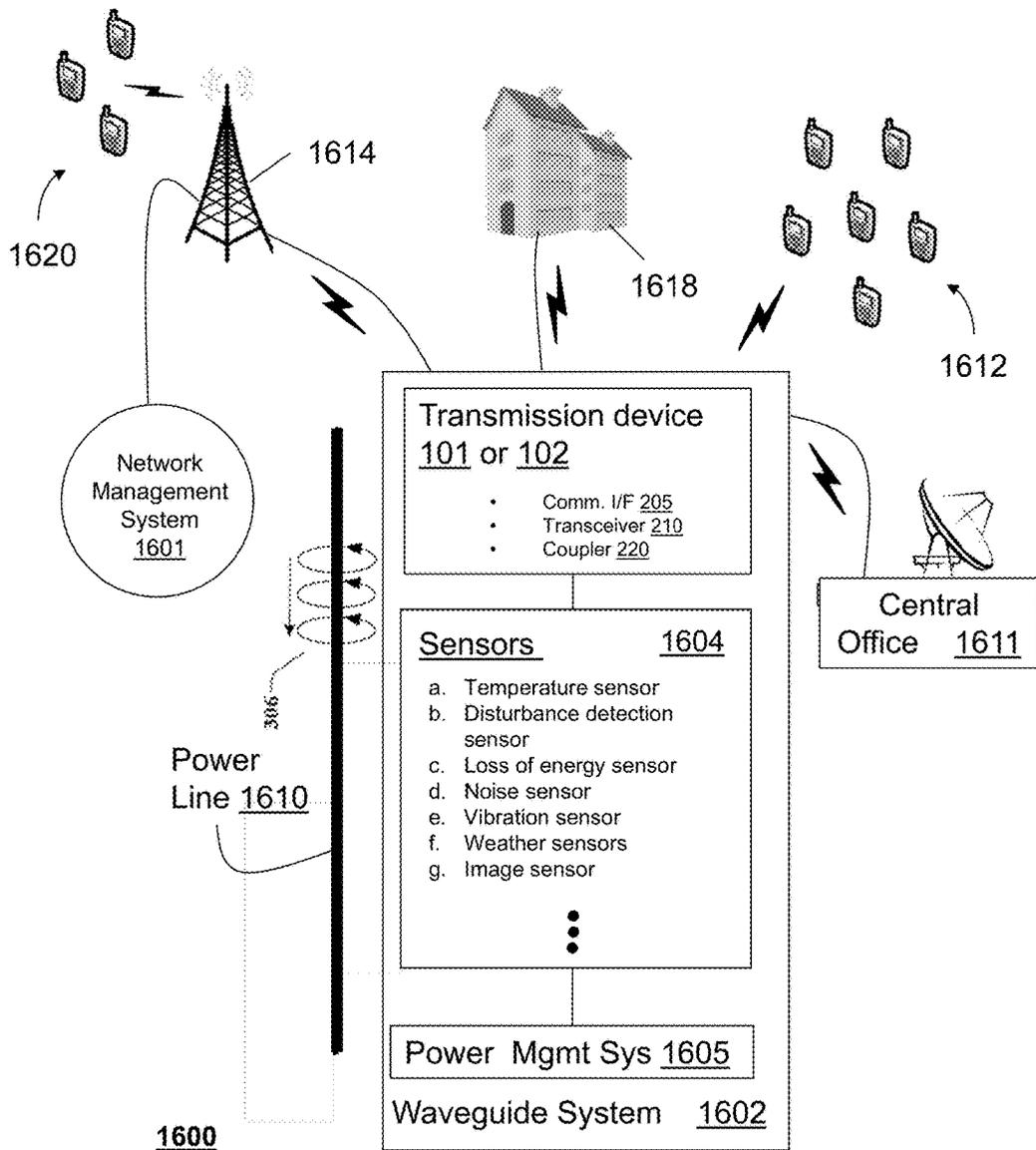
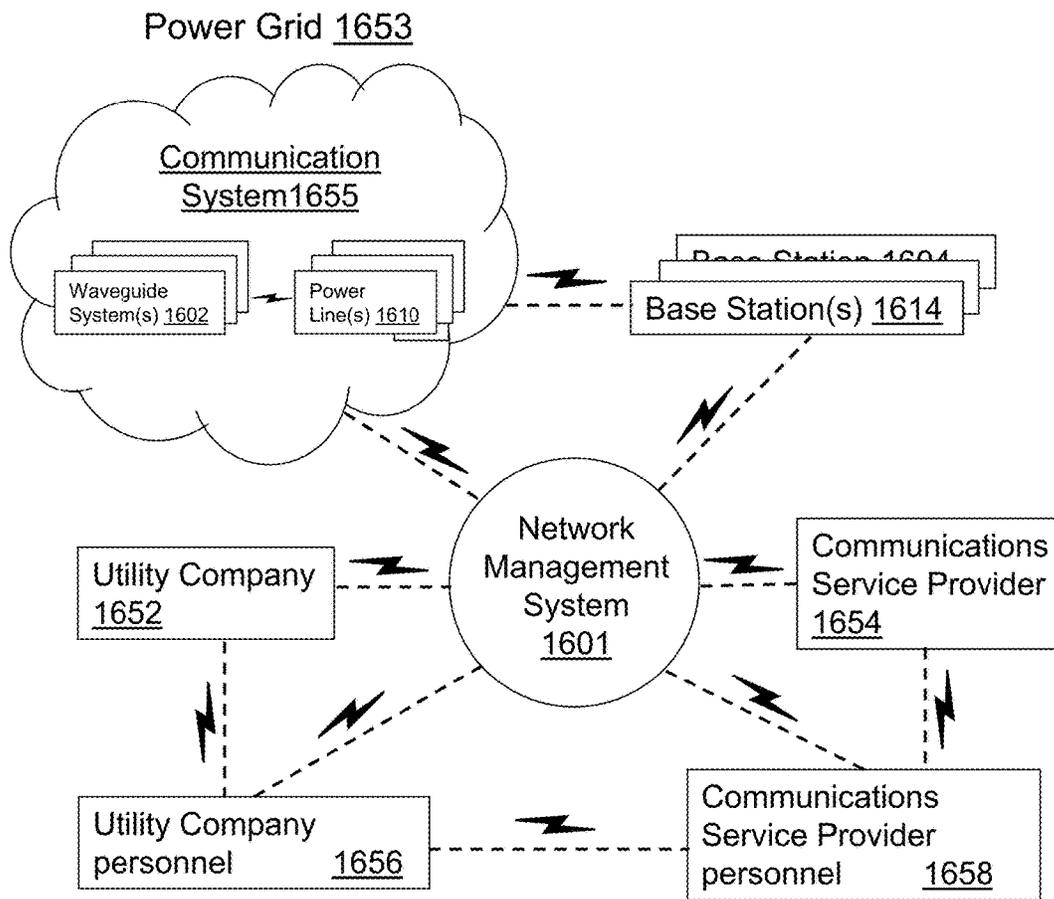
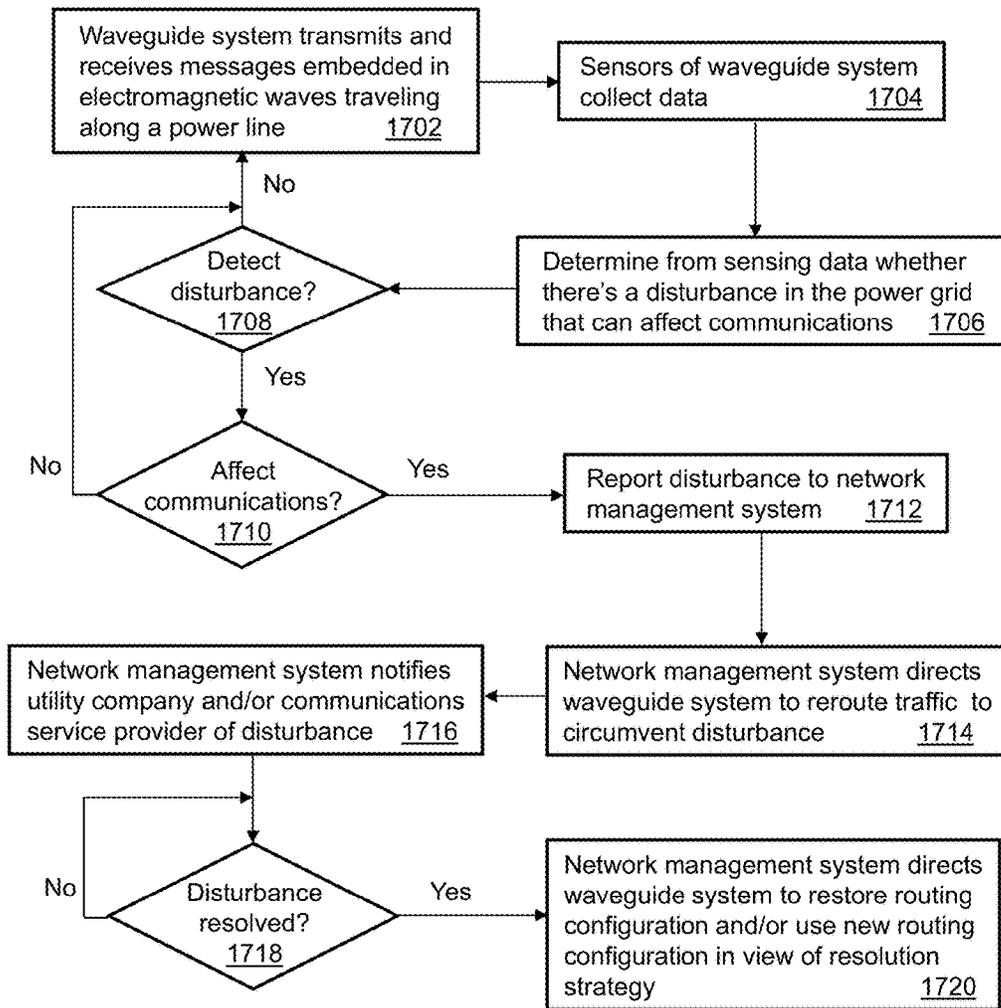


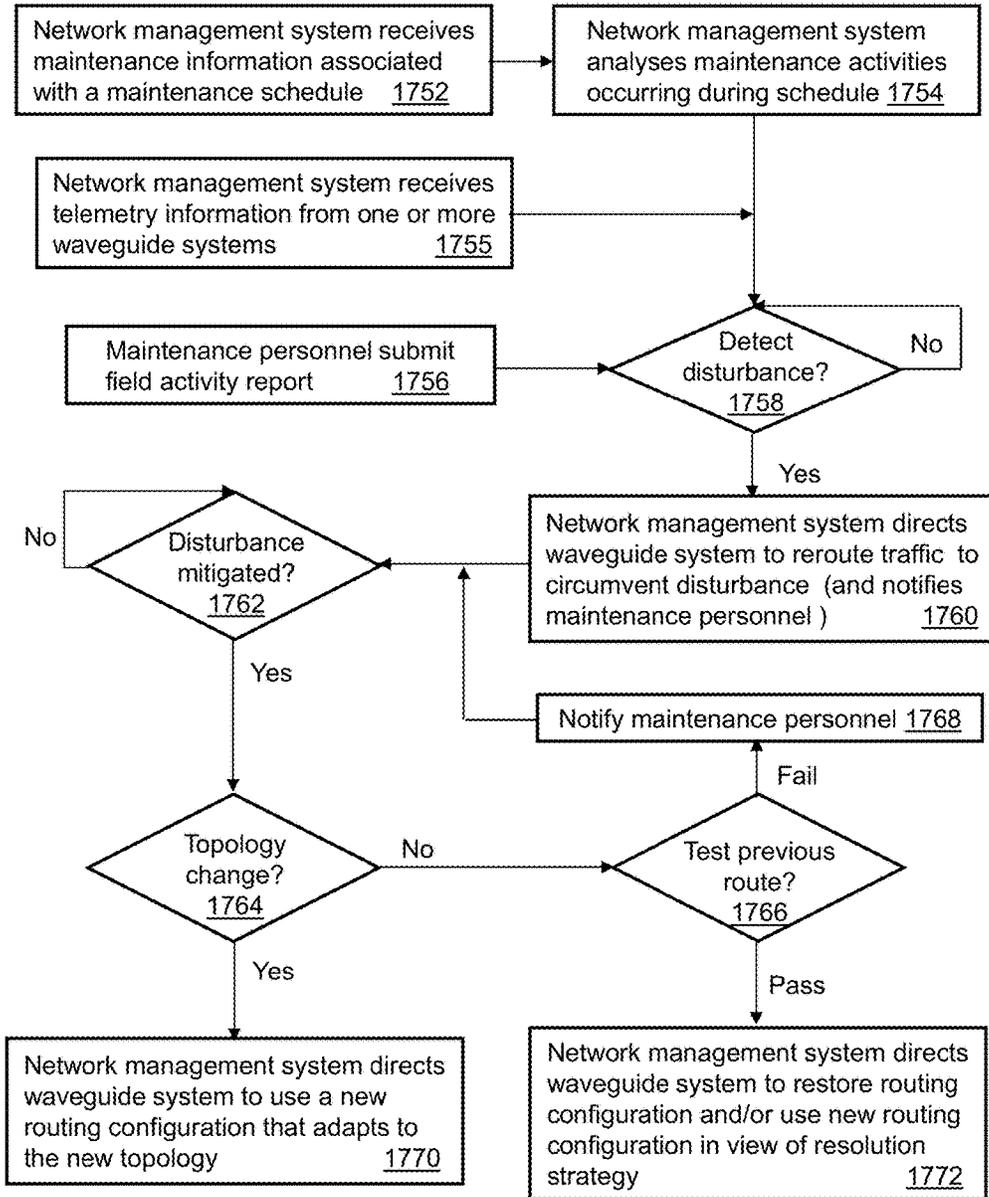
FIG. 16A



1650  
**FIG. 16B**

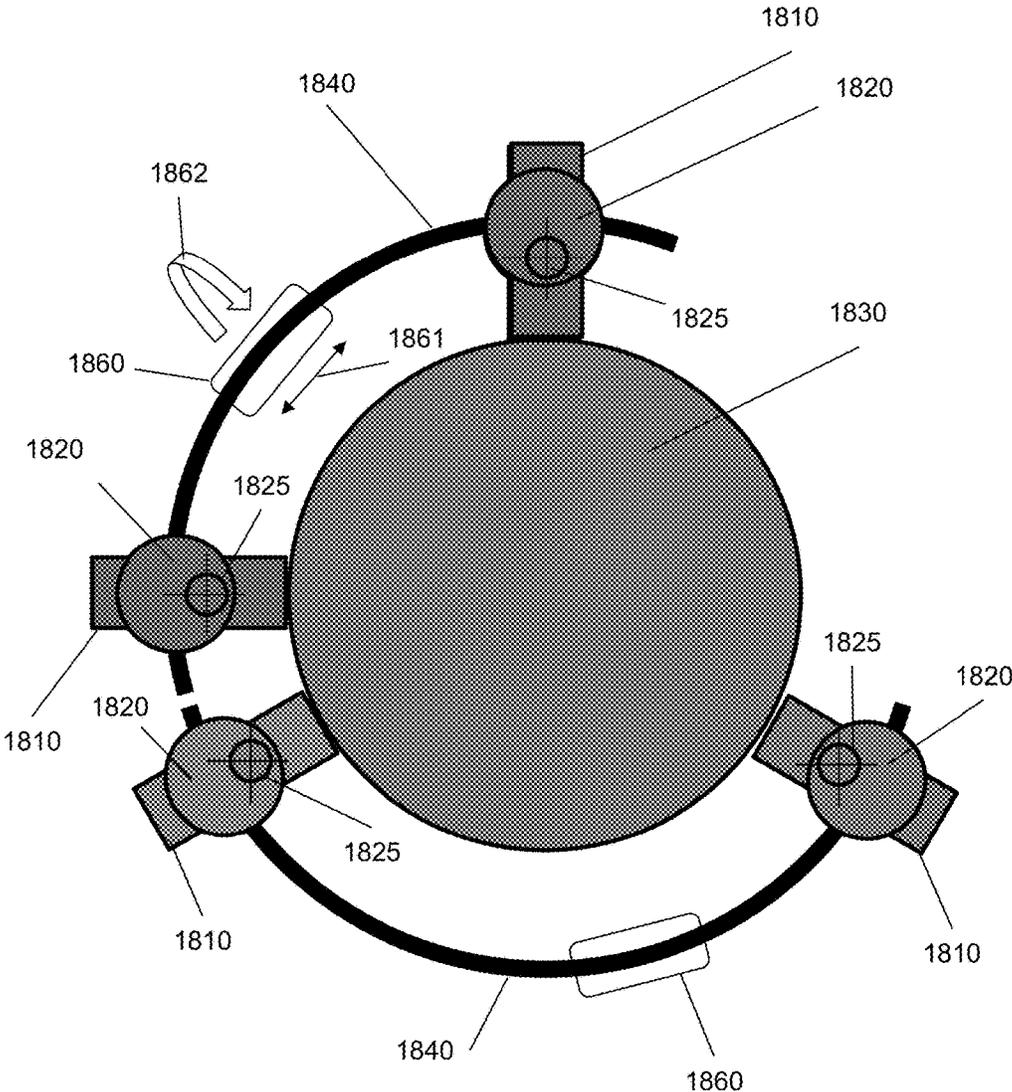


1700  
FIG. 17A

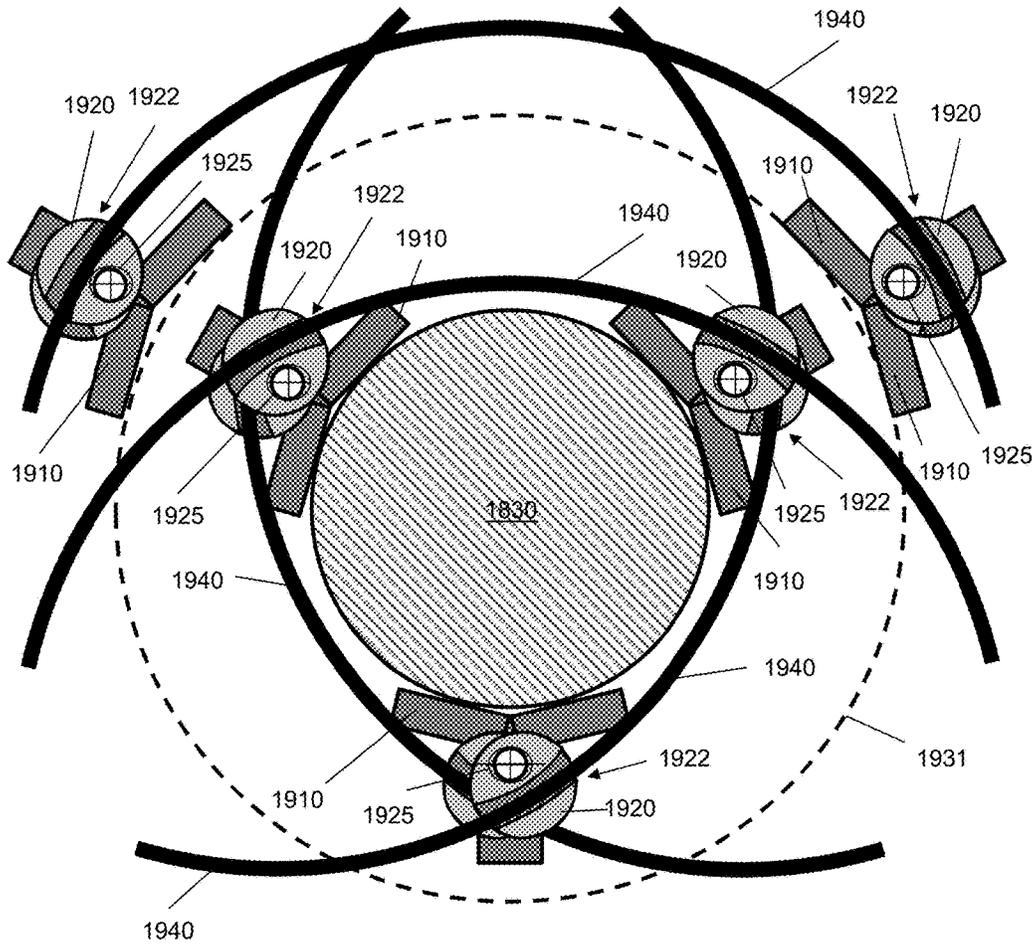


1750

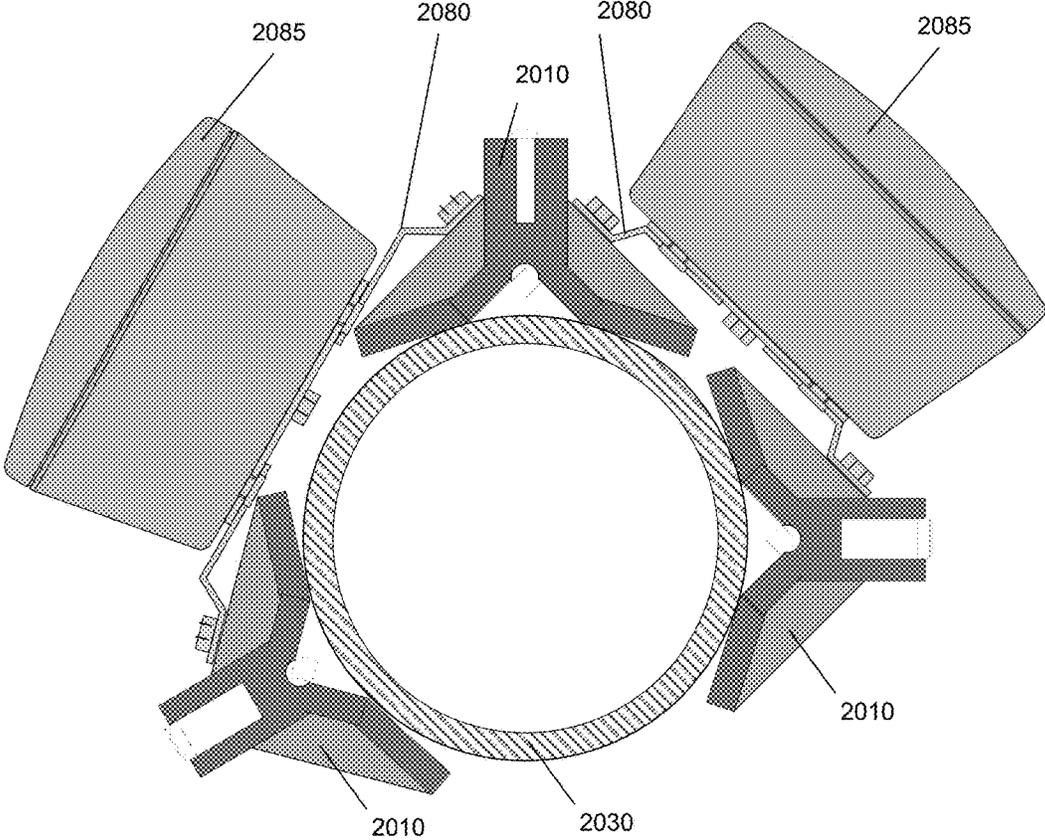
FIG. 17B



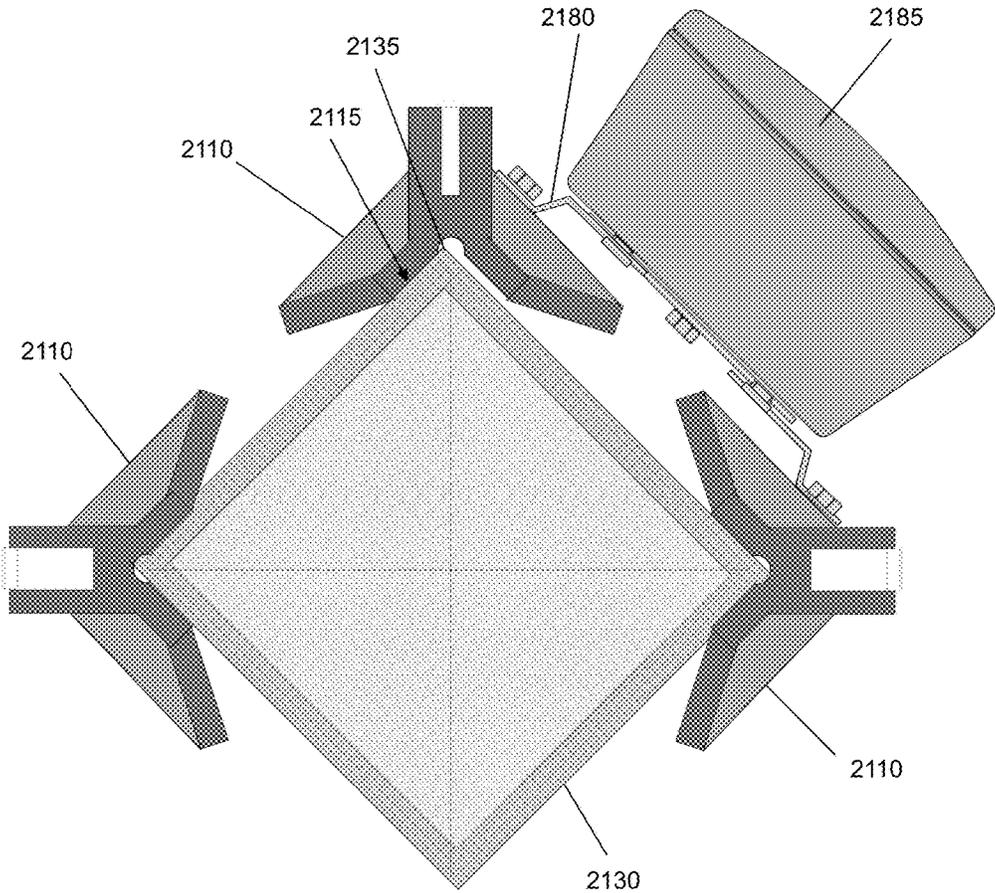
1800  
FIG. 18



1900  
FIG. 19



2000  
FIG. 20



2100  
FIG. 21

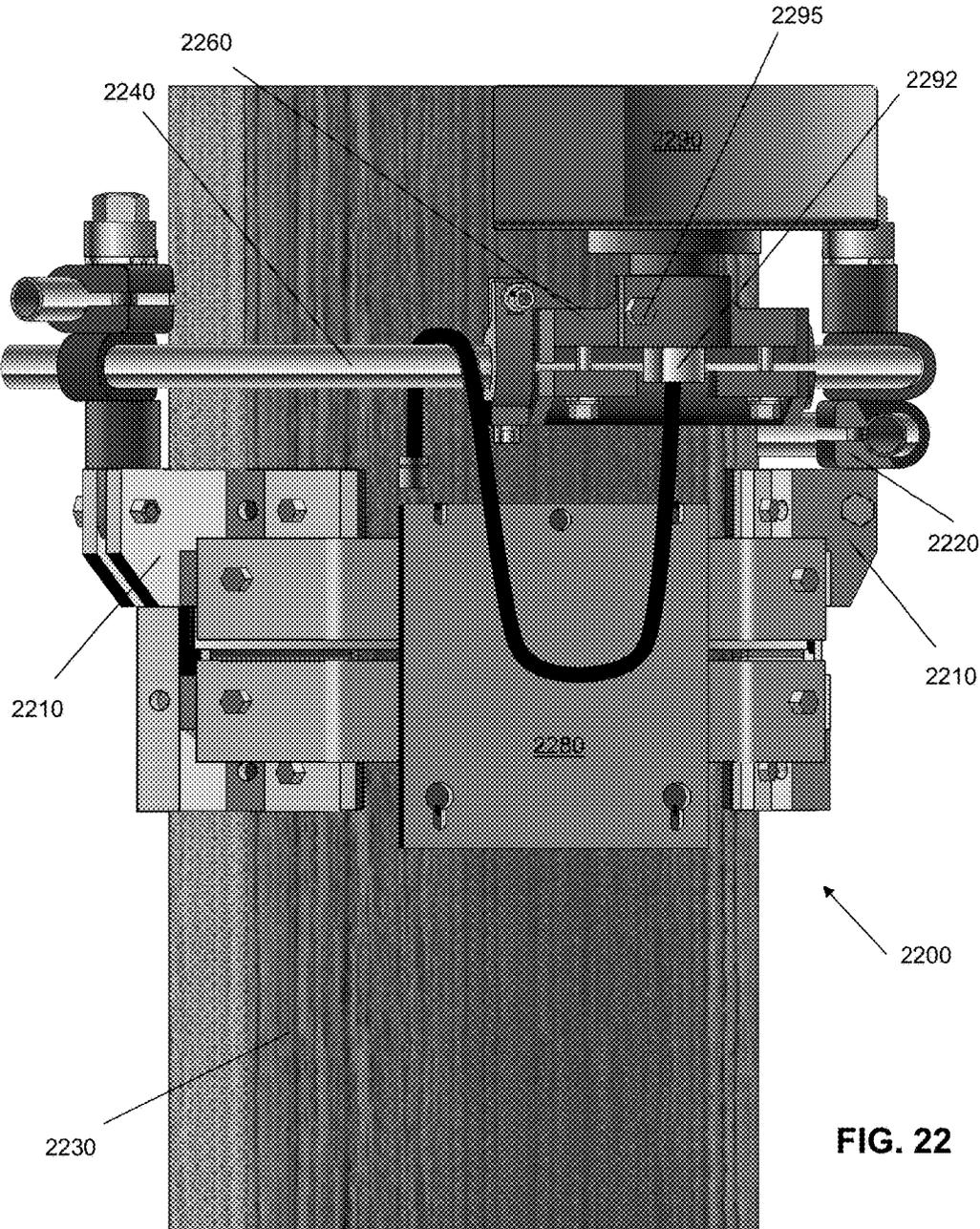


FIG. 22

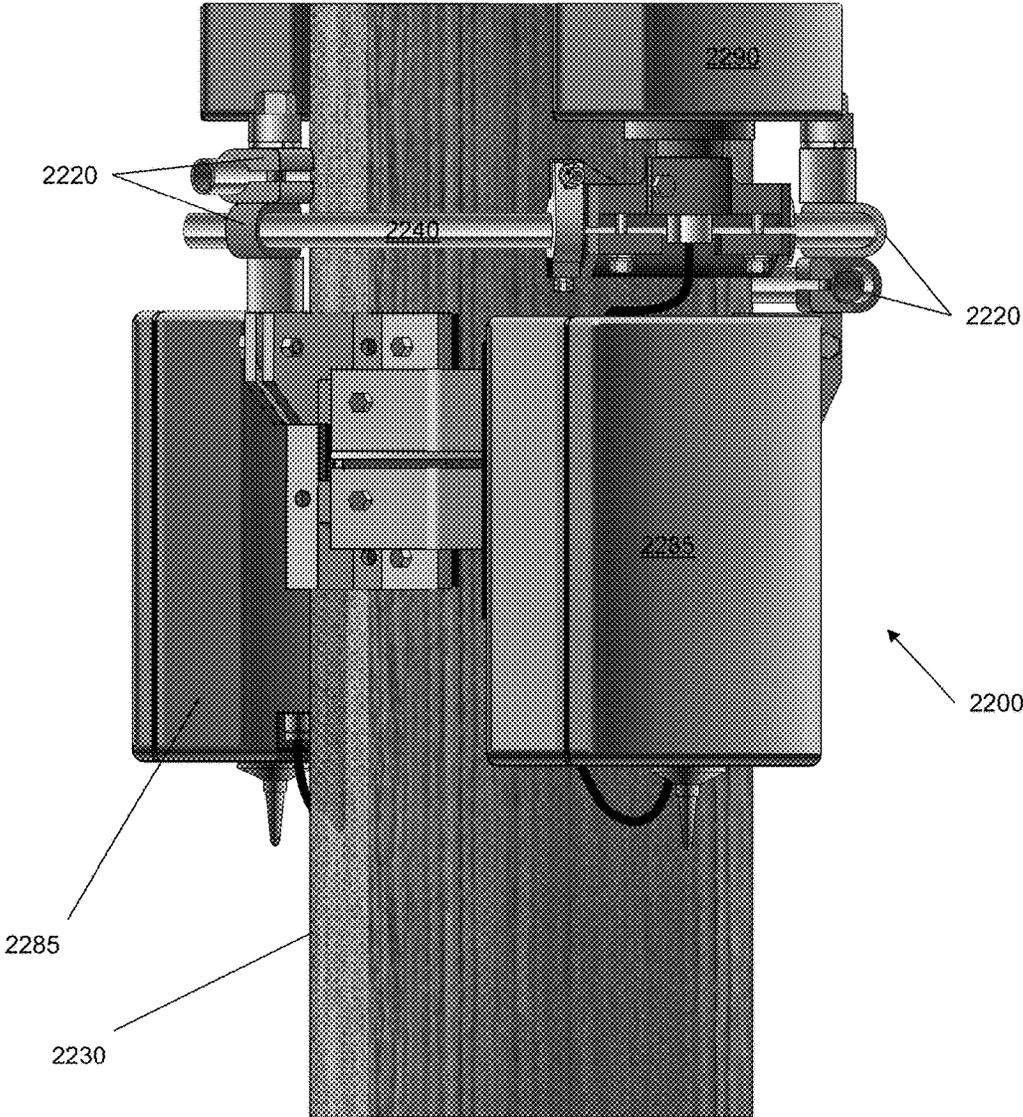
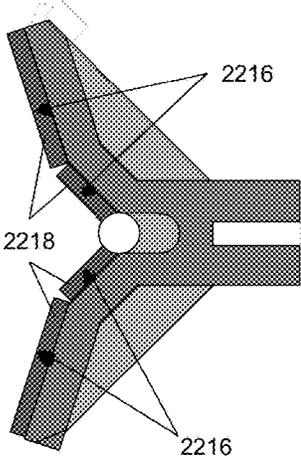
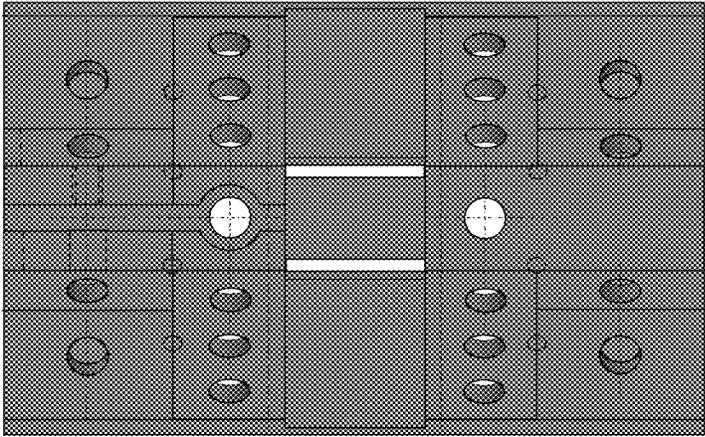


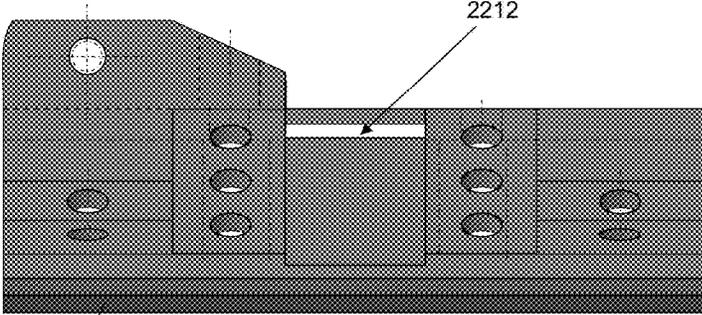
FIG. 23



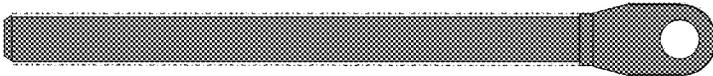
**2210**  
**FIG. 24A**



**2210**  
**FIG. 24B**



**2210**  
**FIG. 24C**



2225  
FIG. 25B

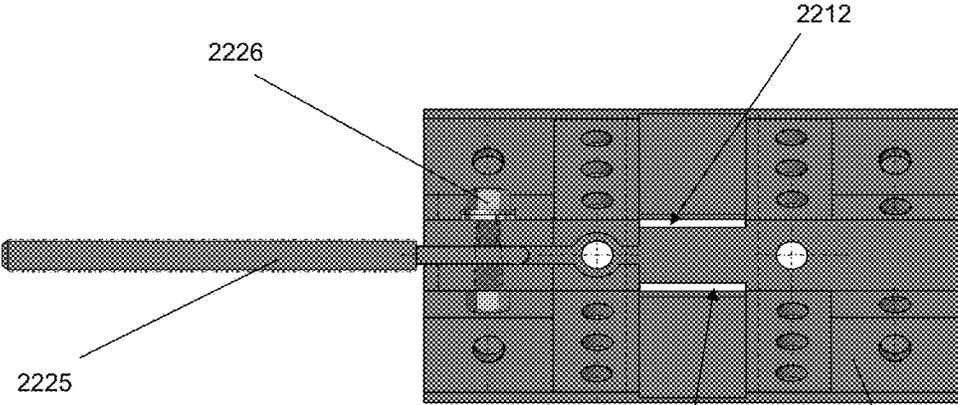


FIG. 25A

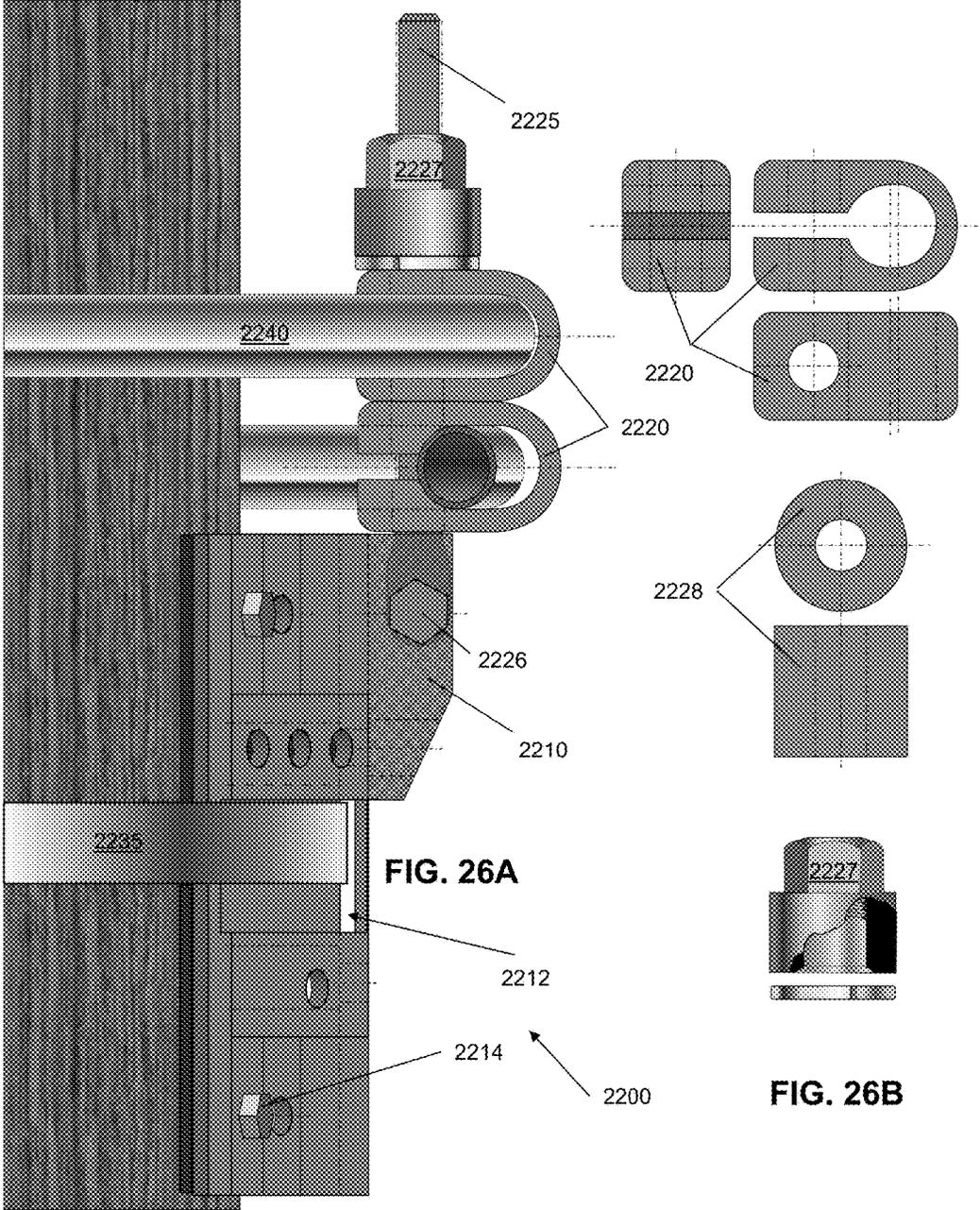


FIG. 26A

FIG. 26B

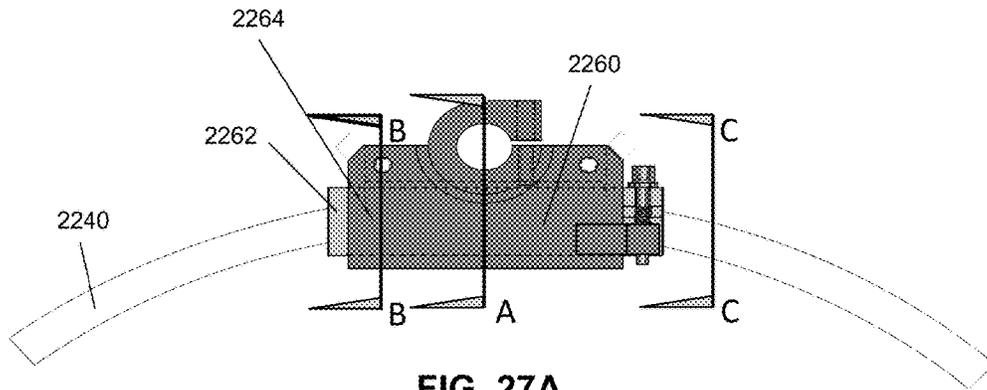


FIG. 27A

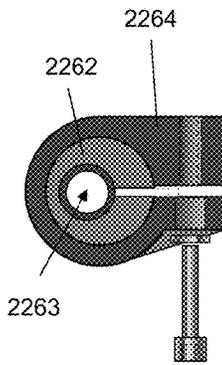


FIG. 27C

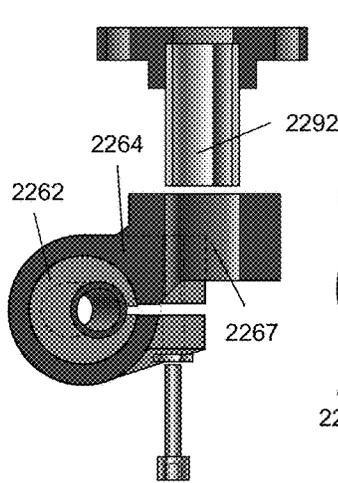


FIG. 27B

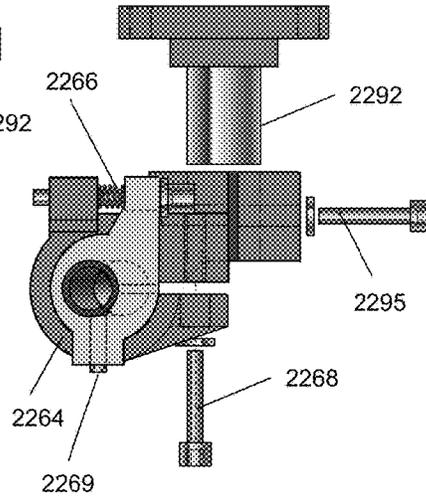


FIG. 27D

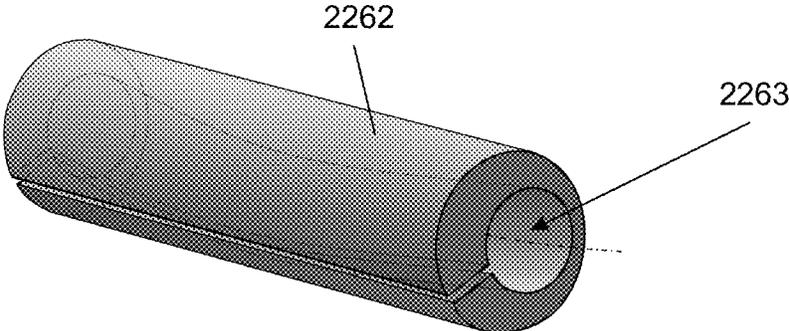


FIG. 28A

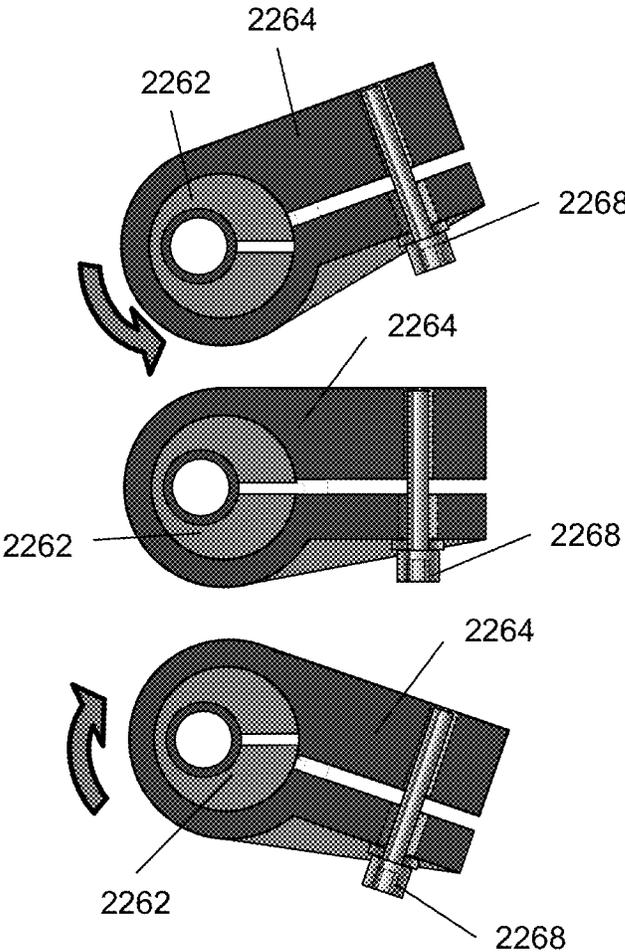


FIG. 28B

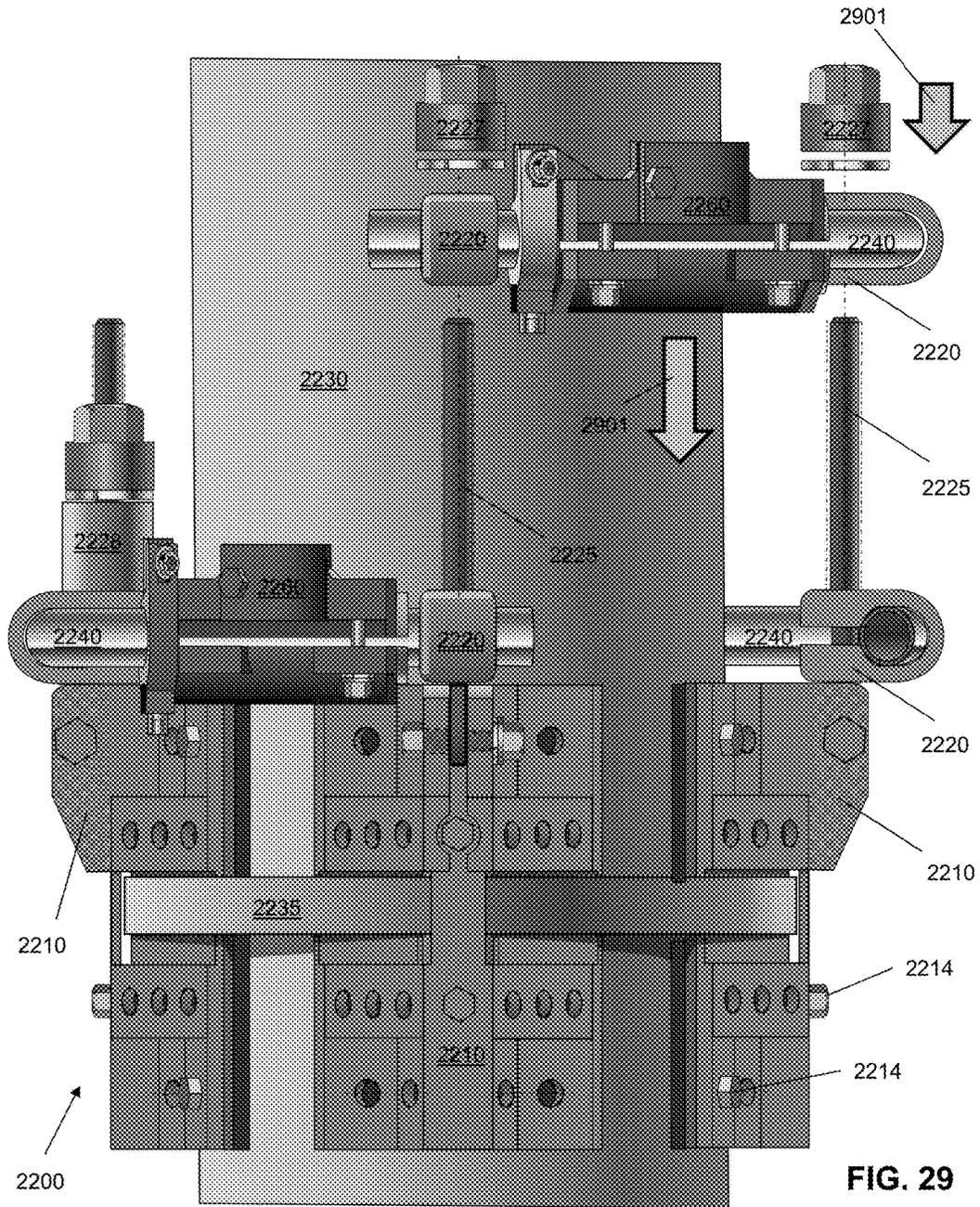


FIG. 29

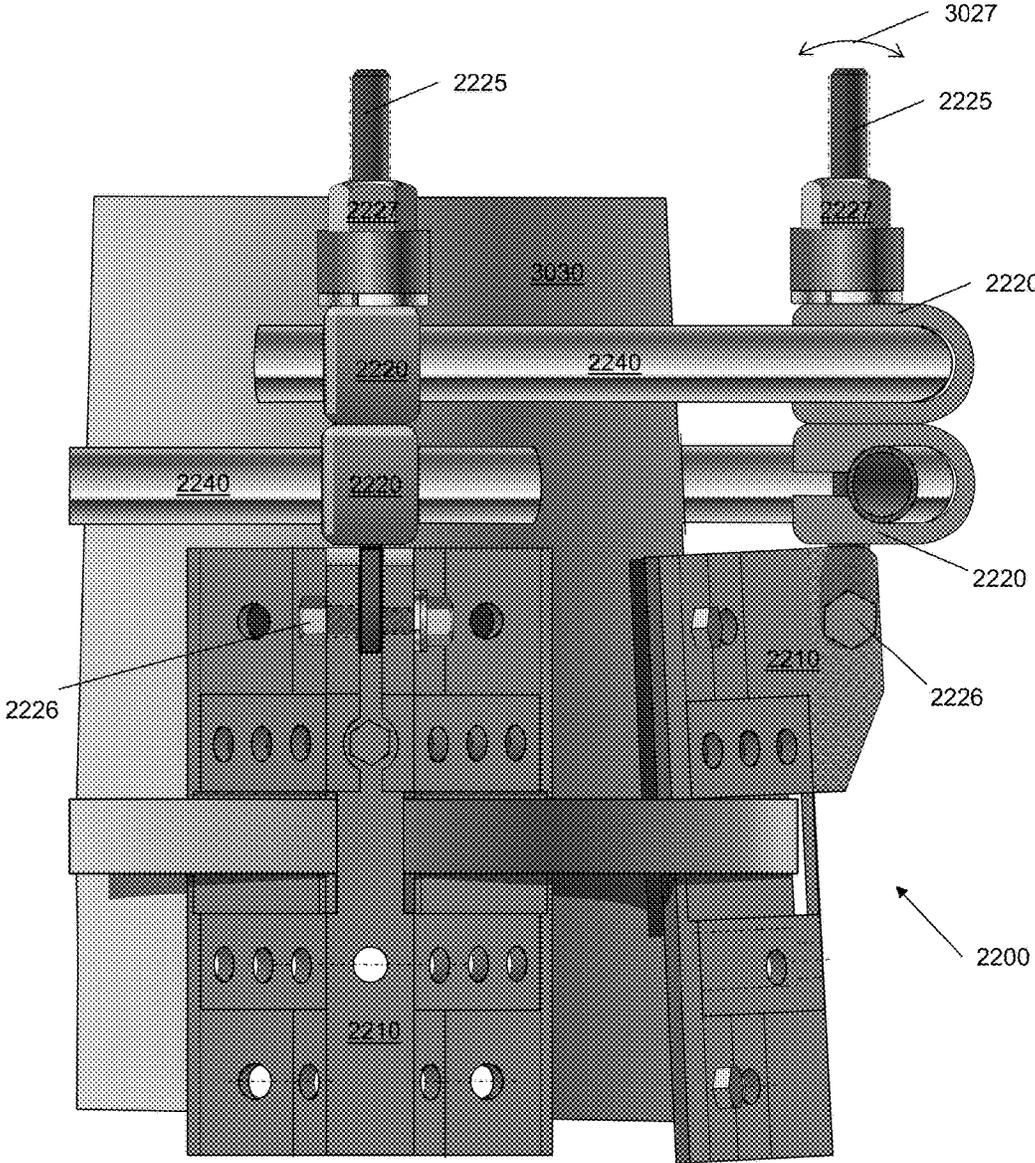


FIG. 30

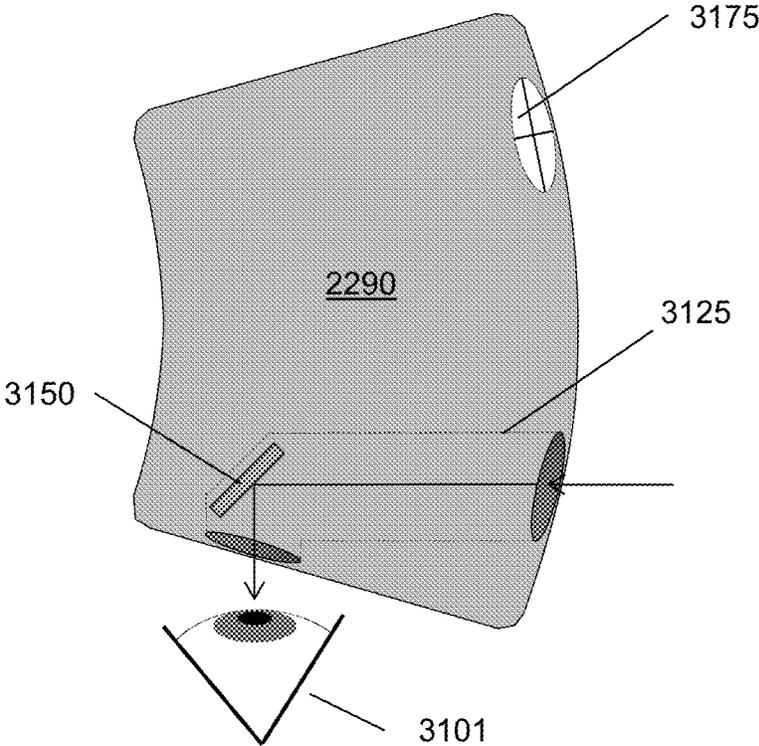


FIG. 31

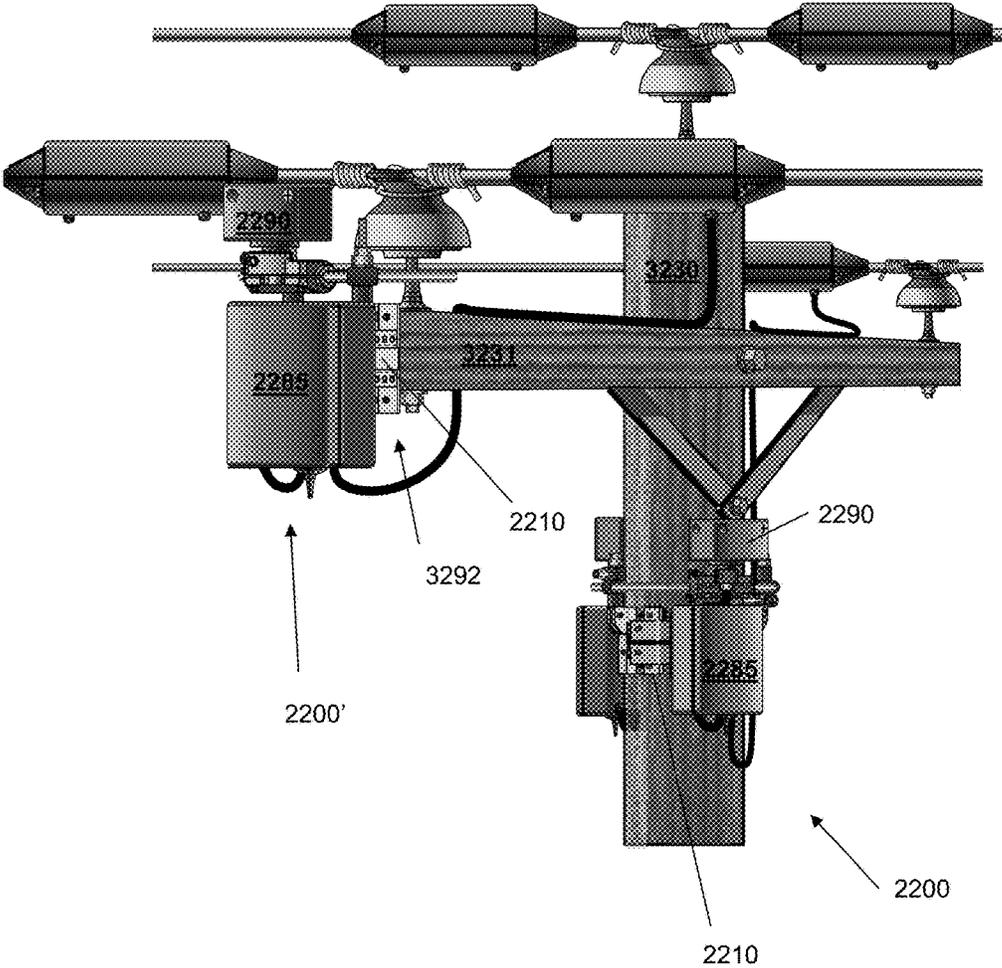


FIG. 32

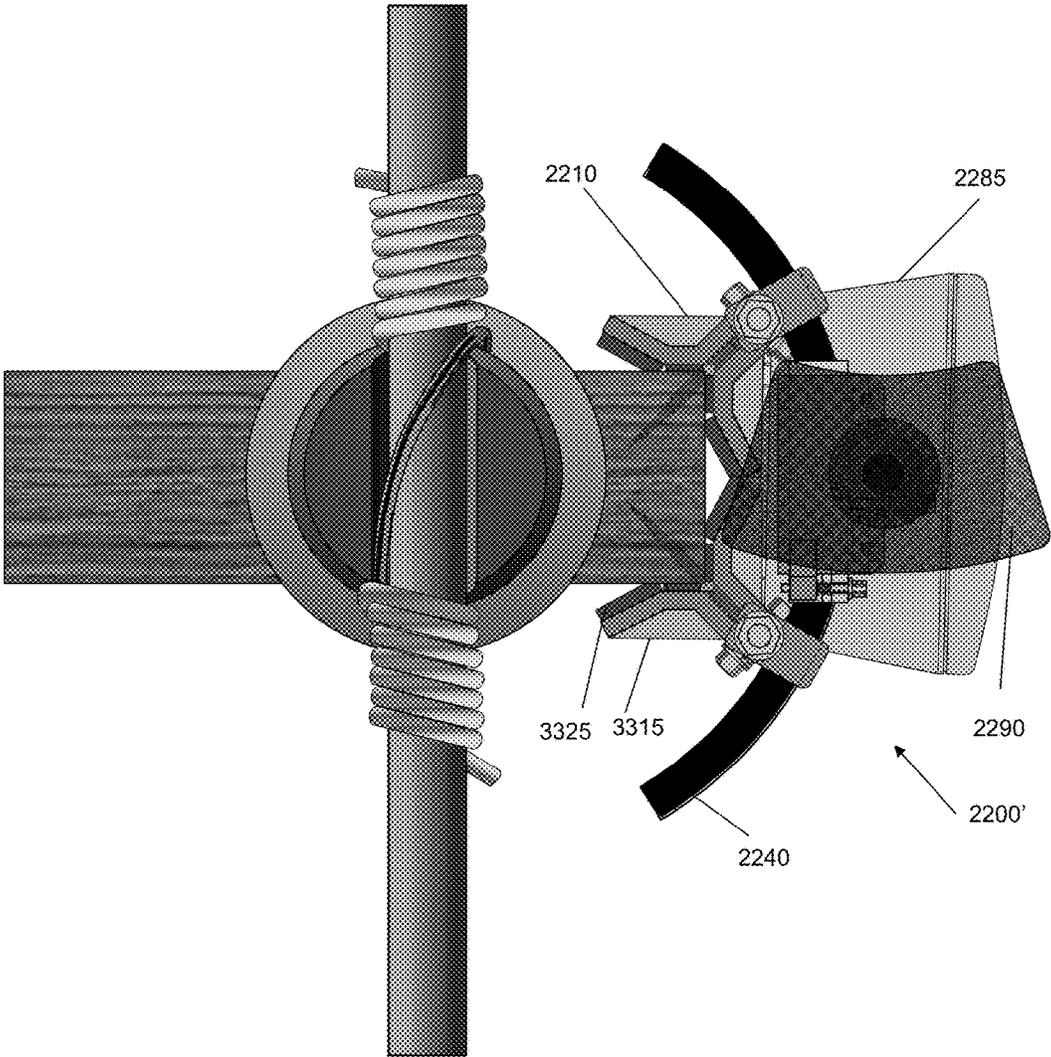


FIG. 33

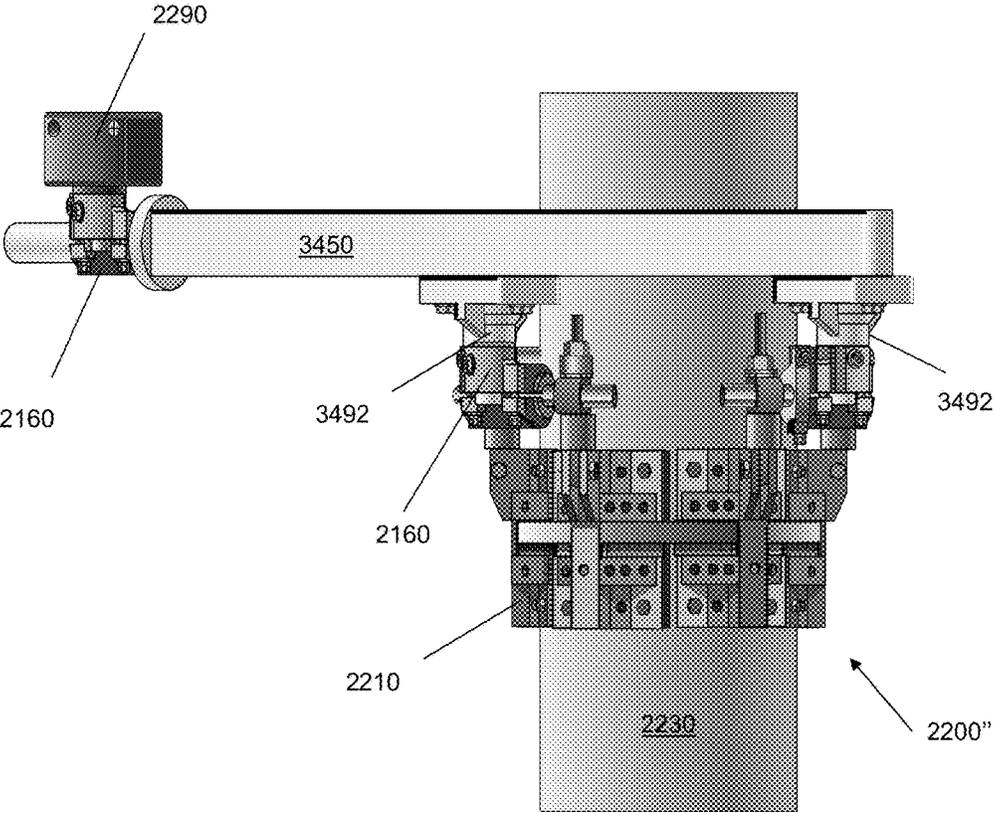


FIG. 34

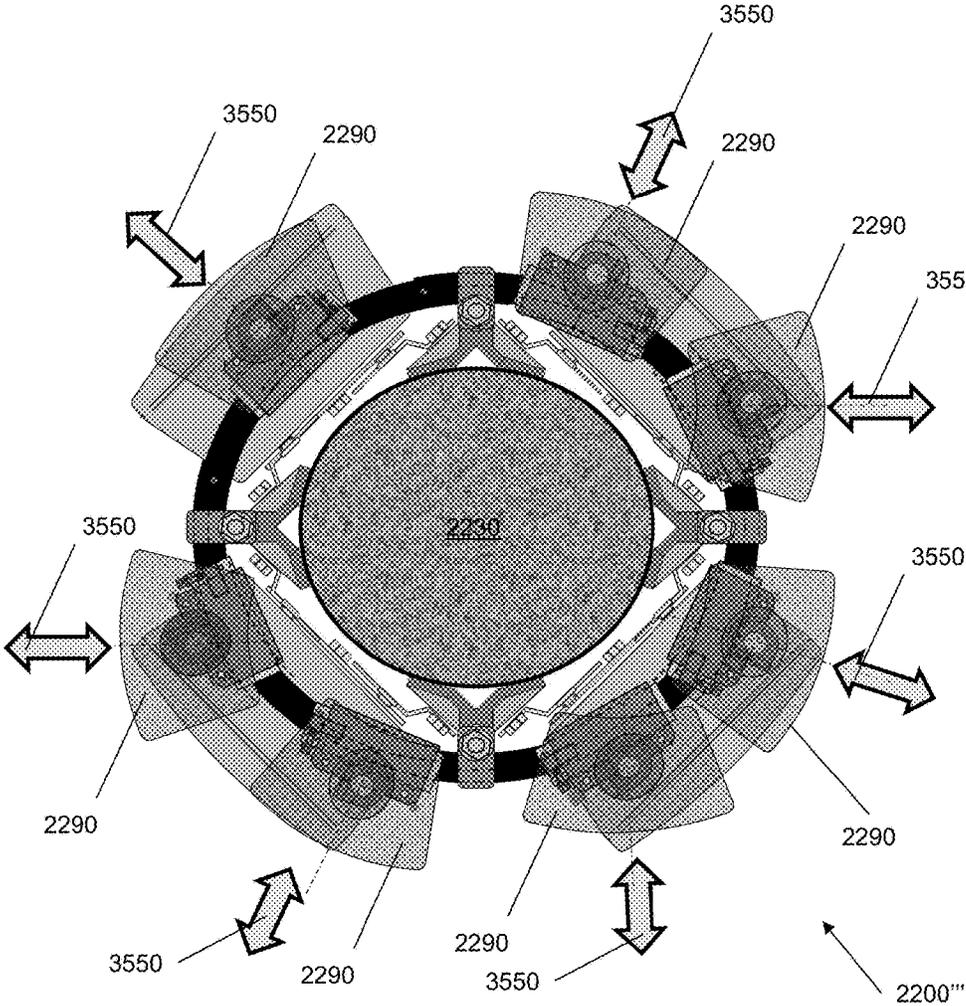
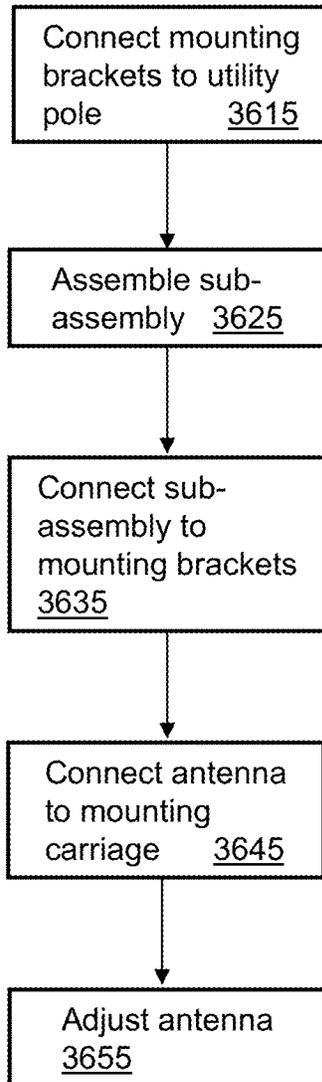
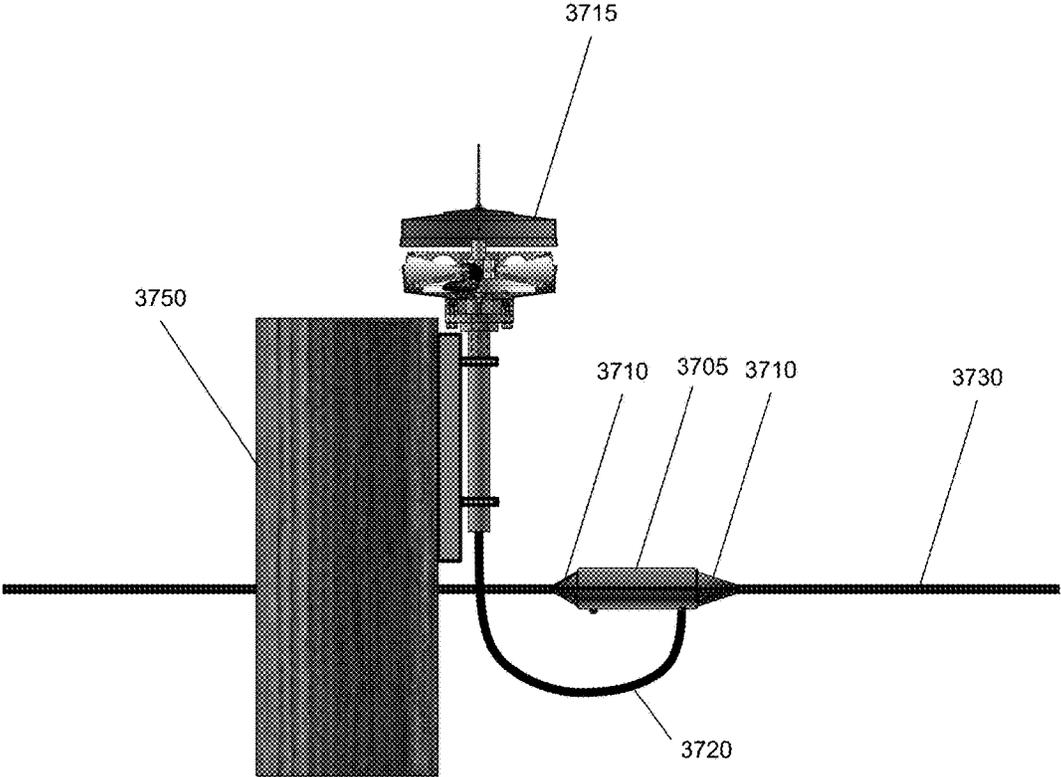


FIG. 35



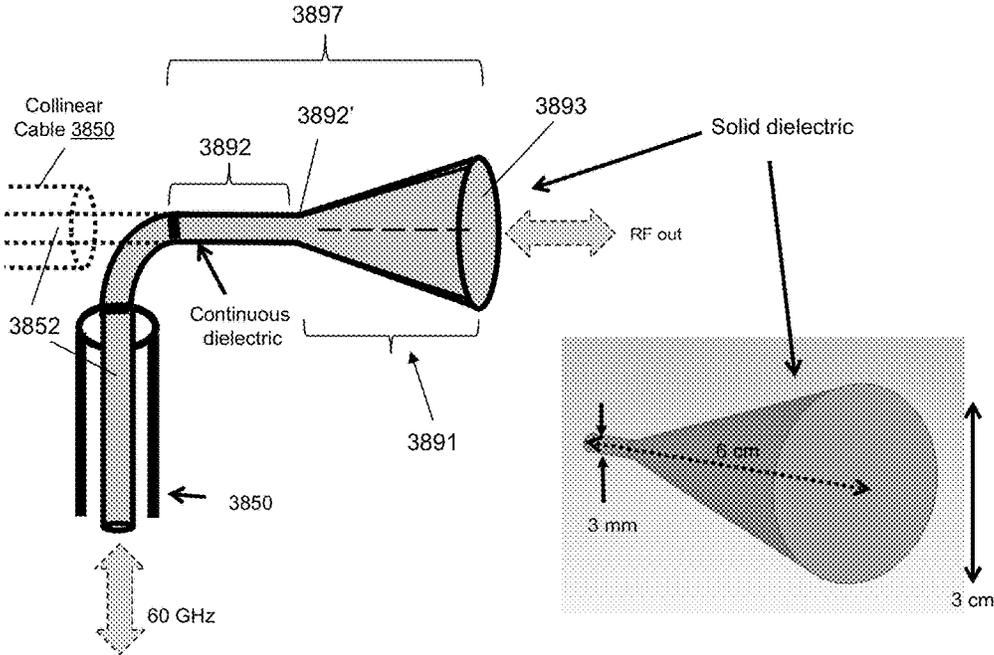
3600

**FIG. 36**



3700  
FIG. 37

**Dielectric Horn Antenna**



**FIG. 38A**

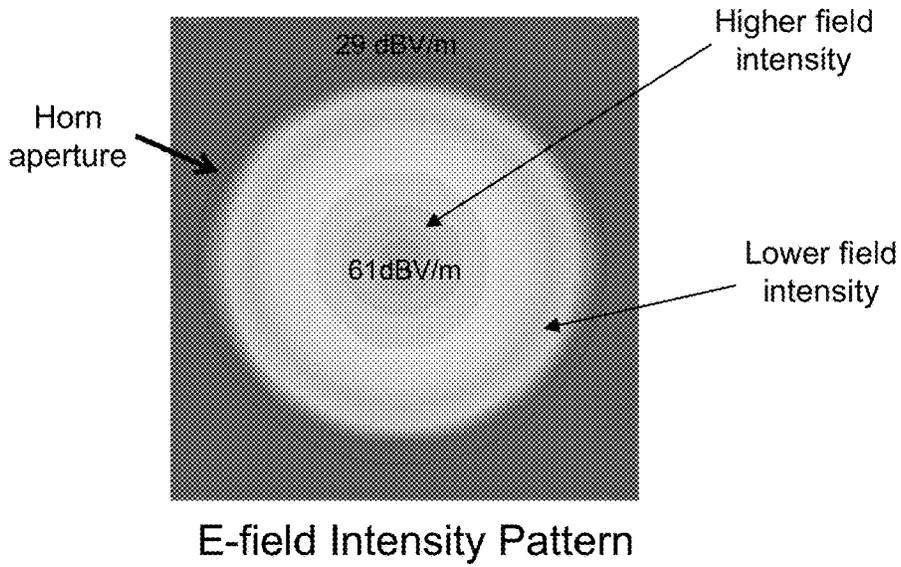
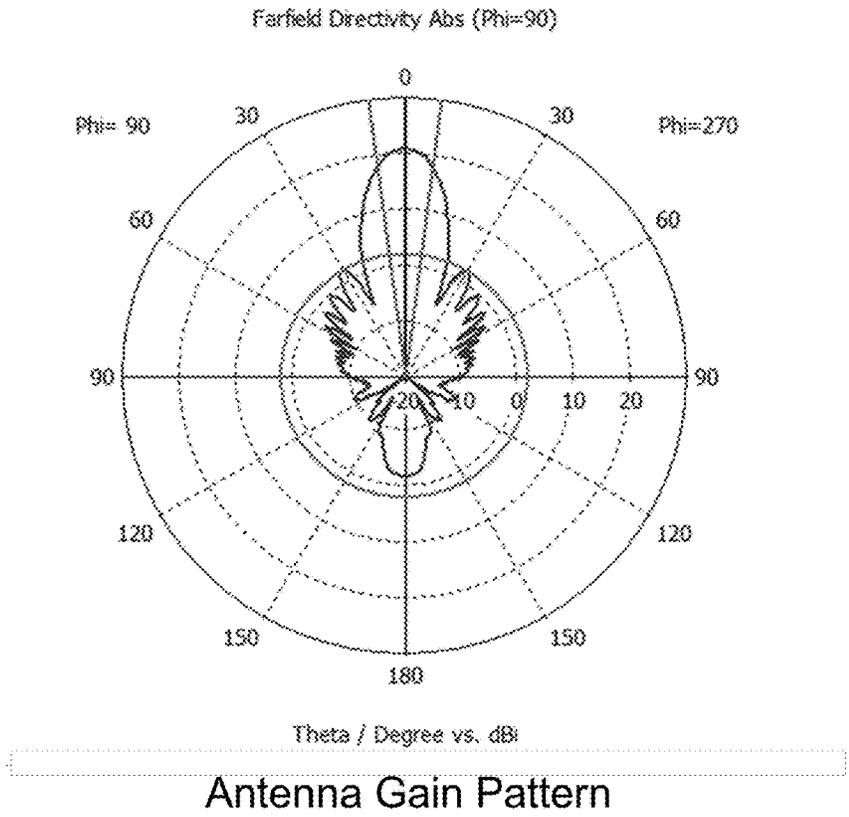


FIG. 38B

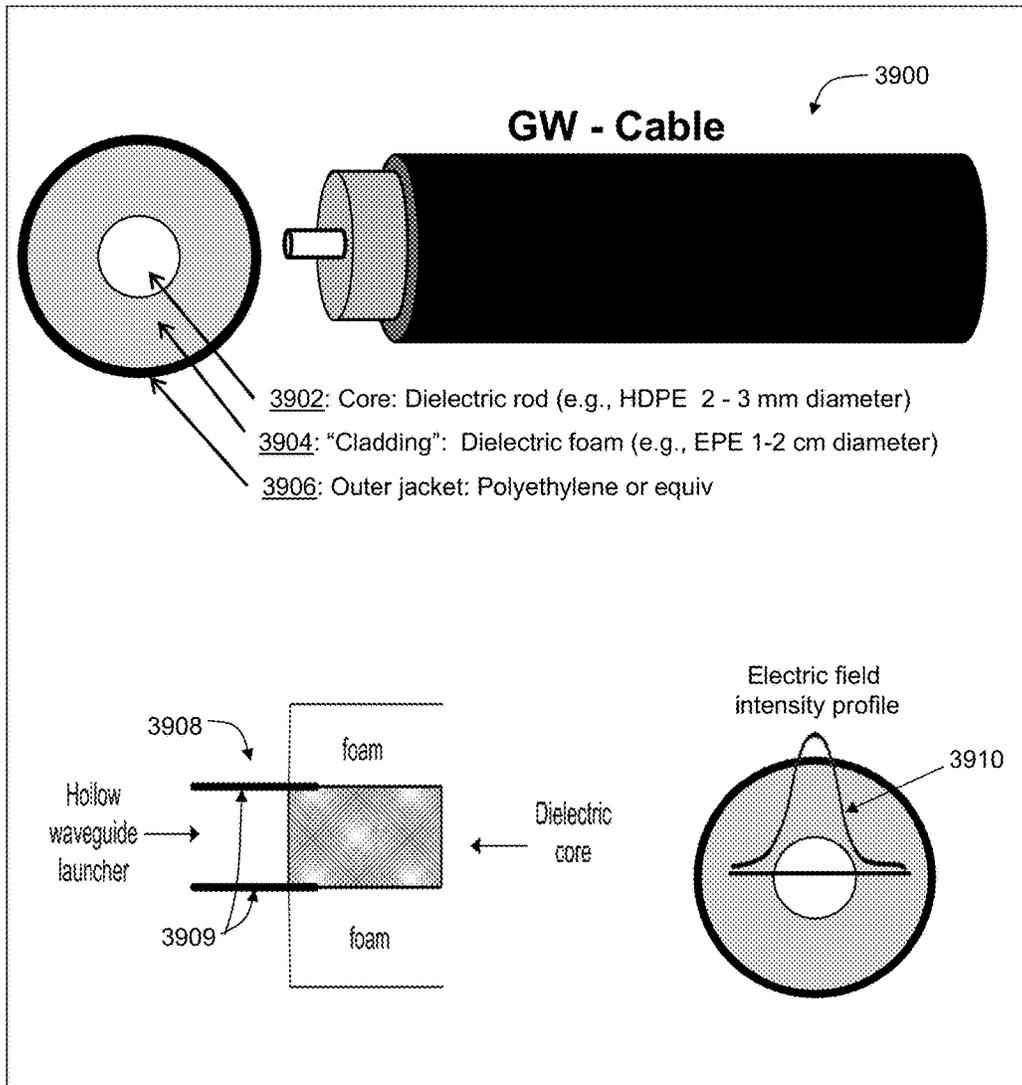


FIG. 39A

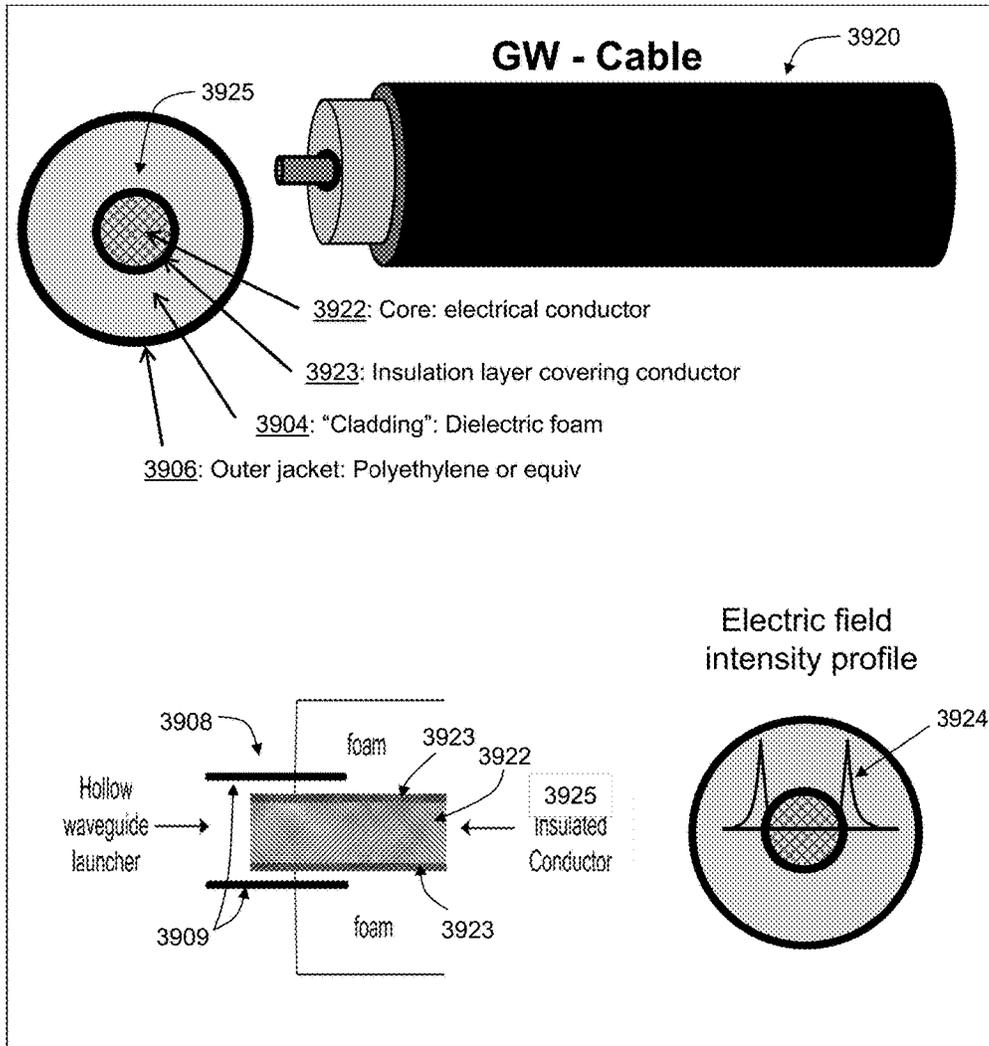


FIG. 39B

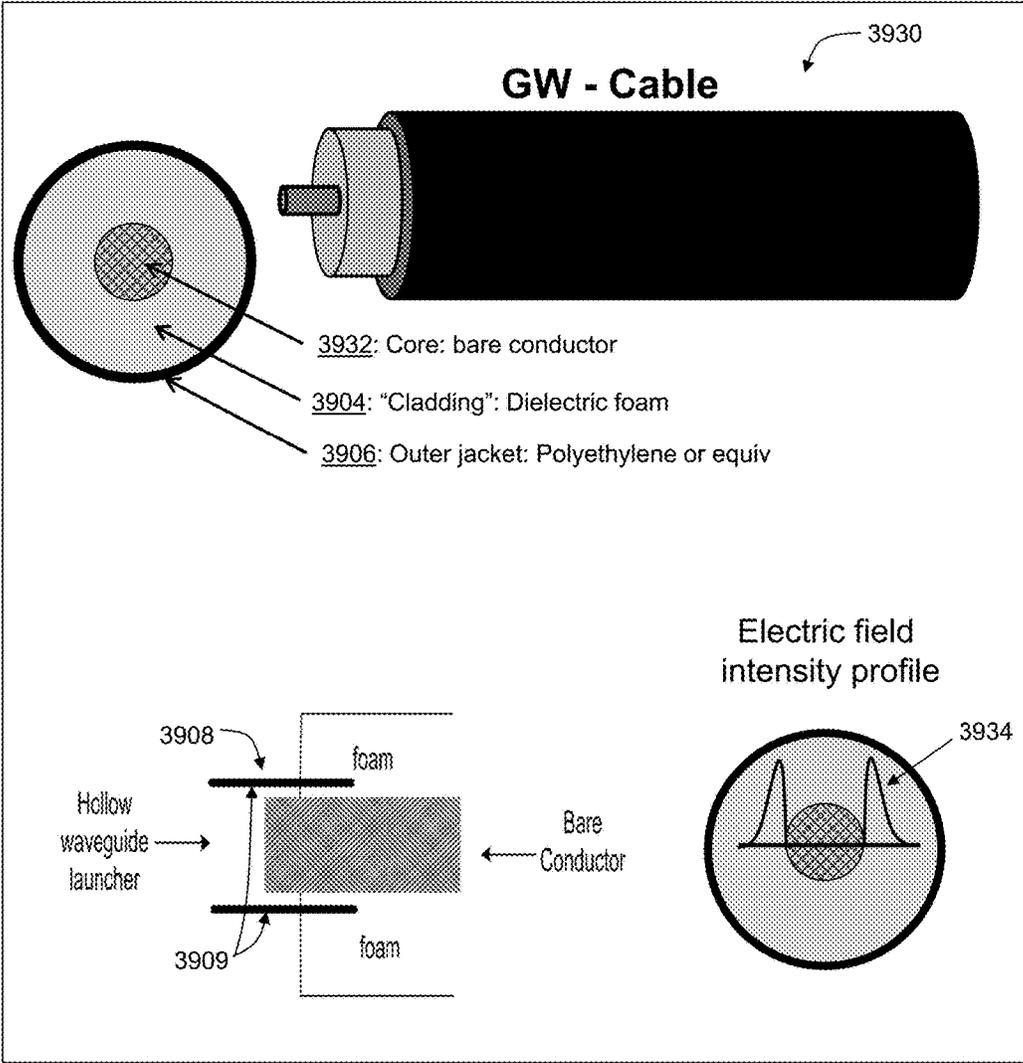


FIG. 39C

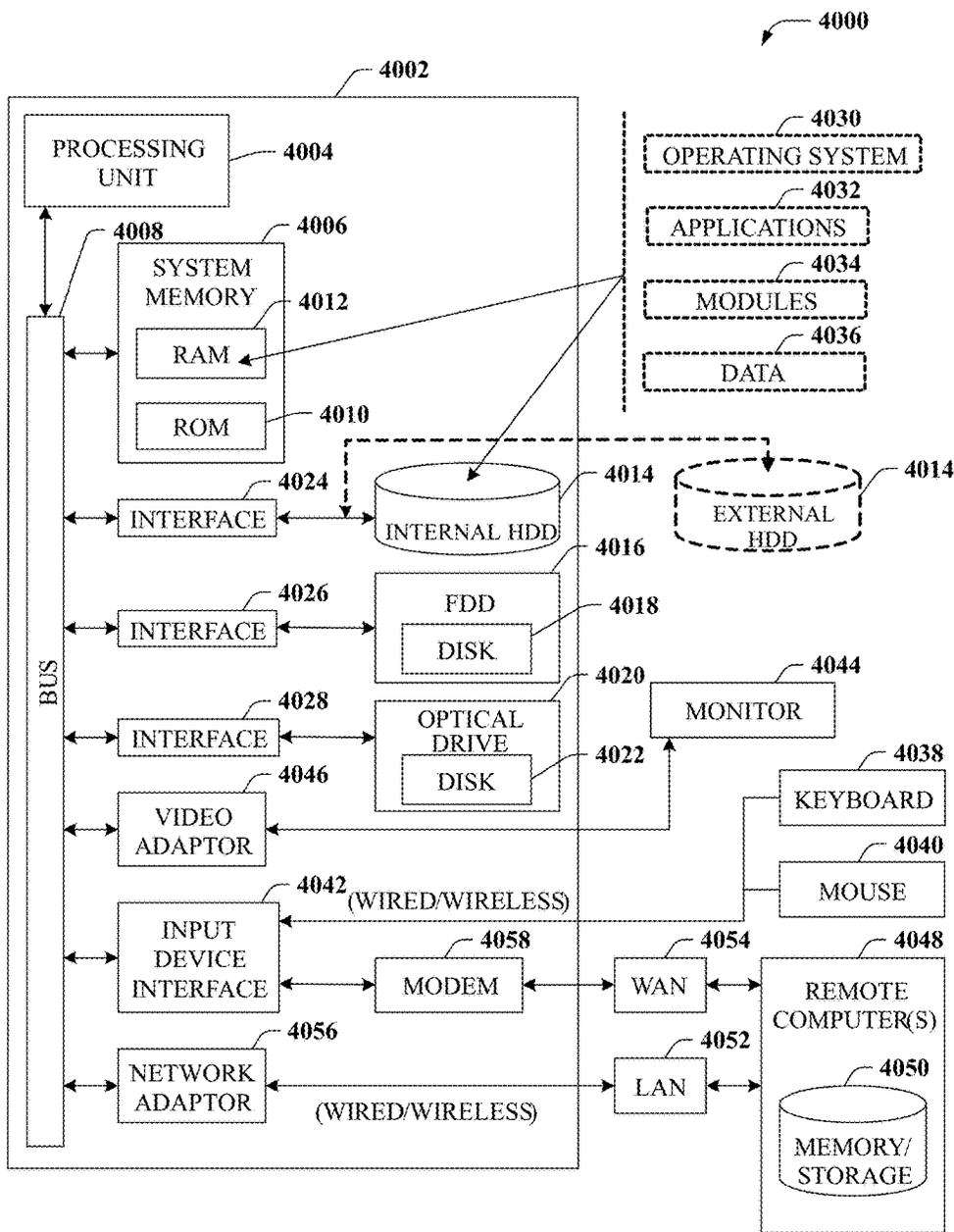


FIG. 40

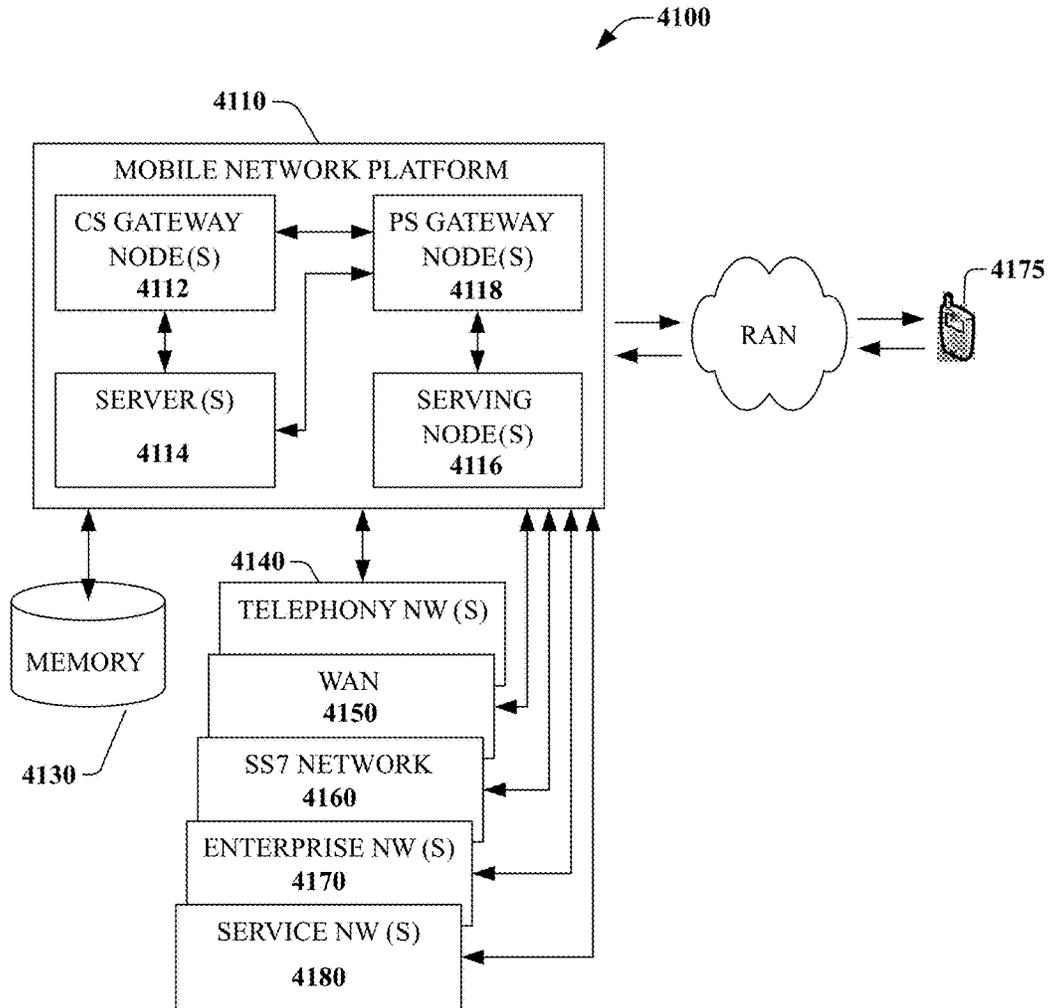
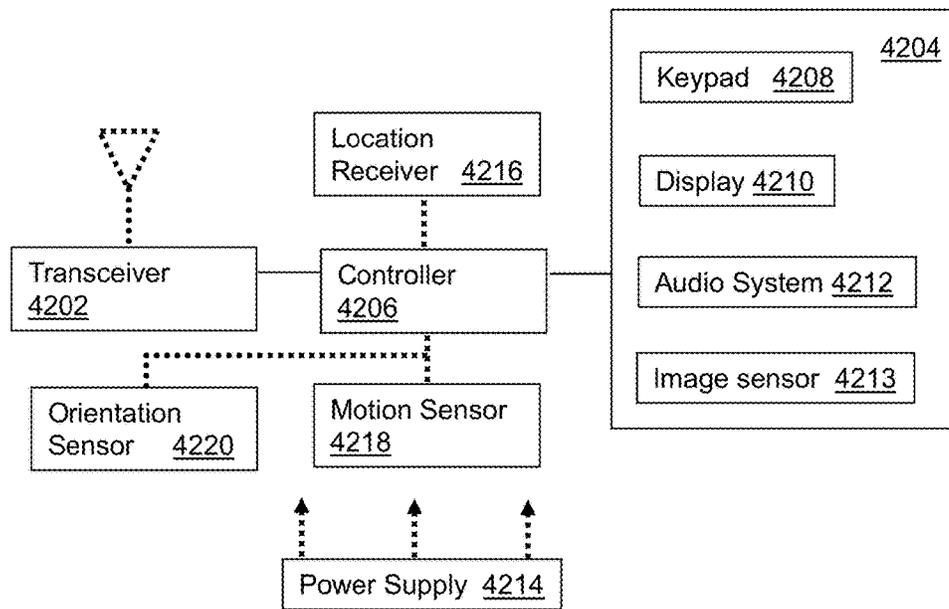


FIG. 41



4200

**FIG. 42**

## METHOD AND APPARATUS FOR MOUNTING NETWORK DEVICES

### CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/372,472 filed on Dec. 8, 2016. The contents of each of the foregoing is/are hereby incorporated by reference into this application as if set forth herein in full.

### FIELD OF THE DISCLOSURE

The subject disclosure relates to mounting network devices, such as guided electromagnetic wave communication devices.

### BACKGROUND

As smart phones and other portable devices increasingly become ubiquitous, and data usage increases, macrocell base station devices and existing wireless infrastructure in turn require higher bandwidth capability in order to address the increased demand. To provide additional mobile bandwidth, small cell deployment is being pursued, with microcells and picocells providing coverage for much smaller areas than traditional macrocells.

In addition, most homes and businesses have grown to rely on broadband data access for services such as voice, video and Internet browsing, etc. Broadband access networks include satellite, 4G or 5G wireless, power line communication, fiber, cable, and telephone networks.

Interference being experienced by network devices along a communication path can degrade the quality of service for users. The interference can be sourced by various devices, including end user devices and other network devices.

### BRIEF DESCRIPTION OF THE DRAWINGS

Reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. 1 is a block diagram illustrating an example, non-limiting embodiment of a guided-wave communications system in accordance with various aspects described herein.

FIG. 2 is a block diagram illustrating an example, non-limiting embodiment of a transmission device in accordance with various aspects described herein.

FIG. 3 is a graphical diagram illustrating an example, non-limiting embodiment of an electromagnetic field distribution in accordance with various aspects described herein.

FIG. 4 is a graphical diagram illustrating an example, non-limiting embodiment of an electromagnetic field distribution in accordance with various aspects described herein.

FIG. 5A is a graphical diagram illustrating an example, non-limiting embodiment of a frequency response in accordance with various aspects described herein.

FIG. 5B is a graphical diagram illustrating example, non-limiting embodiments of a longitudinal cross-section of an insulated wire depicting fields of guided electromagnetic waves at various operating frequencies in accordance with various aspects described herein.

FIG. 6 is a graphical diagram illustrating an example, non-limiting embodiment of an electromagnetic field distribution in accordance with various aspects described herein.

FIG. 7 is a block diagram illustrating an example, non-limiting embodiment of an arc coupler in accordance with various aspects described herein.

FIG. 8 is a block diagram illustrating an example, non-limiting embodiment of an arc coupler in accordance with various aspects described herein.

FIG. 9A is a block diagram illustrating an example, non-limiting embodiment of a stub coupler in accordance with various aspects described herein.

FIG. 9B is a diagram illustrating an example, non-limiting embodiment of an electromagnetic distribution in accordance with various aspects described herein.

FIGS. 10A and 10B are block diagrams illustrating example, non-limiting embodiments of couplers and transceivers in accordance with various aspects described herein.

FIG. 11 is a block diagram illustrating an example, non-limiting embodiment of a dual stub coupler in accordance with various aspects described herein.

FIG. 12 is a block diagram illustrating an example, non-limiting embodiment of a repeater system in accordance with various aspects described herein.

FIG. 13 illustrates a block diagram illustrating an example, non-limiting embodiment of a bidirectional repeater in accordance with various aspects described herein.

FIG. 14 is a block diagram illustrating an example, non-limiting embodiment of a waveguide system in accordance with various aspects described herein.

FIG. 15 is a block diagram illustrating an example, non-limiting embodiment of a guided-wave communications system in accordance with various aspects described herein.

FIGS. 16A & 16B are block diagrams illustrating an example, non-limiting embodiment of a system for managing a power grid communication system in accordance with various aspects described herein.

FIG. 17A illustrates a flow diagram of an example, non-limiting embodiment of a method for detecting and mitigating disturbances occurring in a communication network of the system of FIGS. 16A and 16B.

FIG. 17B illustrates a flow diagram of an example, non-limiting embodiment of a method for detecting and mitigating disturbances occurring in a communication network of the system of FIGS. 16A and 16B.

FIGS. 18-21 are block diagrams illustrating example, non-limiting embodiments of systems for supporting one or more network devices on utility poles in accordance with various aspects described herein.

FIGS. 22-23 are block diagrams illustrating example, non-limiting embodiments of systems for supporting one or more network devices on utility poles in accordance with various aspects described herein.

FIGS. 24A-24C, 25A-25B, 26A-26B, 27A-27D, 28A-28B, 29-31 are block diagrams illustrating example, non-limiting embodiments of components that can be used with the systems of FIGS. 22-23 that support one or more network devices on utility poles in accordance with various aspects described herein.

FIGS. 32-35 are block diagrams illustrating example, non-limiting embodiments of systems for supporting one or more network devices on utility poles in accordance with various aspects described herein.

FIG. 36 illustrates a flow diagram of an example, non-limiting embodiment of a method for assembling and adjusting a system for supporting one or more network devices on utility poles in accordance with various aspects described herein.

FIG. 37 illustrates a block diagram illustrating an example, non-limiting embodiment of a network device in accordance with various aspects described herein.

FIGS. 38A and 38B are block diagrams illustrating example, non-limiting embodiments of a dielectric antenna and corresponding gain and field intensity plots in accordance with various aspects described herein.

FIGS. 39A, 39B, and 39C are block diagrams illustrating example, non-limiting embodiment of a transmission medium for propagating guided electromagnetic waves.

FIG. 40 is a block diagram of an example, non-limiting embodiment of a computing environment in accordance with various aspects described herein.

FIG. 41 is a block diagram of an example, non-limiting embodiment of a mobile network platform in accordance with various aspects described herein.

FIG. 42 is a block diagram of an example, non-limiting embodiment of a communication device in accordance with various aspects described herein.

#### DETAILED DESCRIPTION

One or more embodiments are now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the various embodiments. It is evident, however, that the various embodiments can be practiced without these details (and without applying to any particular networked environment or standard).

In an embodiment, a guided wave communication system is presented for sending and receiving communication signals such as data or other signaling via guided electromagnetic waves. The guided electromagnetic waves include, for example, surface waves or other electromagnetic waves that are bound to or guided by a transmission medium. It will be appreciated that a variety of transmission media can be utilized with guided wave communications without departing from example embodiments. Examples of such transmission media can include one or more of the following, either alone or in one or more combinations: wires, whether insulated or not, and whether single-stranded or multi-stranded; conductors of other shapes or configurations including wire bundles, cables, rods, rails, pipes; non-conductors such as dielectric pipes, rods, rails, or other dielectric members; combinations of conductors and dielectric materials; or other guided wave transmission media.

The inducement of guided electromagnetic waves on a transmission medium can be independent of any electrical potential, charge or current that is injected or otherwise transmitted through the transmission medium as part of an electrical circuit. For example, in the case where the transmission medium is a wire, it is to be appreciated that while a small current in the wire may be formed in response to the propagation of the guided waves along the wire, this can be due to the propagation of the electromagnetic wave along the wire surface, and is not formed in response to electrical potential, charge or current that is injected into the wire as part of an electrical circuit. The electromagnetic waves traveling on the wire therefore do not require a circuit to propagate along the wire surface. The wire therefore is a single wire transmission line that is not part of a circuit. Also, in some embodiments, a wire is not necessary, and the electromagnetic waves can propagate along a single line transmission medium that is not a wire.

More generally, "guided electromagnetic waves" or "guided waves" as described by the subject disclosure are affected by the presence of a physical object that is at least a part of the transmission medium (e.g., a bare wire or other

conductor, a dielectric, an insulated wire, a conduit or other hollow element, a bundle of insulated wires that is coated, covered or surrounded by a dielectric or insulator or other wire bundle, or another form of solid, liquid or otherwise non-gaseous transmission medium) so as to be at least partially bound to or guided by the physical object and so as to propagate along a transmission path of the physical object. Such a physical object can operate as at least a part of a transmission medium that guides, by way of an interface of the transmission medium (e.g., an outer surface, inner surface, an interior portion between the outer and the inner surfaces or other boundary between elements of the transmission medium), the propagation of guided electromagnetic waves, which in turn can carry energy, data and/or other signals along the transmission path from a sending device to a receiving device.

Unlike free space propagation of wireless signals such as unguided (or unbounded) electromagnetic waves that decrease in intensity inversely by the square of the distance traveled by the unguided electromagnetic waves, guided electromagnetic waves can propagate along a transmission medium with less loss in magnitude per unit distance than experienced by unguided electromagnetic waves.

Unlike electrical signals, guided electromagnetic waves can propagate from a sending device to a receiving device without requiring a separate electrical return path between the sending device and the receiving device. As a consequence, guided electromagnetic waves can propagate from a sending device to a receiving device along a transmission medium having no conductive components (e.g., a dielectric strip), or via a transmission medium having no more than a single conductor (e.g., a single bare wire or insulated wire). Even if a transmission medium includes one or more conductive components and the guided electromagnetic waves propagating along the transmission medium generate currents that flow in the one or more conductive components in a direction of the guided electromagnetic waves, such guided electromagnetic waves can propagate along the transmission medium from a sending device to a receiving device without requiring a flow of opposing currents on an electrical return path between the sending device and the receiving device.

In a non-limiting illustration, consider electrical systems that transmit and receive electrical signals between sending and receiving devices by way of conductive media. Such systems generally rely on electrically separate forward and return paths. For instance, consider a coaxial cable having a center conductor and a ground shield that are separated by an insulator. Typically, in an electrical system a first terminal of a sending (or receiving) device can be connected to the center conductor, and a second terminal of the sending (or receiving) device can be connected to the ground shield. If the sending device injects an electrical signal in the center conductor via the first terminal, the electrical signal will propagate along the center conductor causing forward currents in the center conductor, and return currents in the ground shield. The same conditions apply for a two terminal receiving device.

In contrast, consider a guided wave communication system such as described in the subject disclosure, which can utilize different embodiments of a transmission medium (including among others a coaxial cable) for transmitting and receiving guided electromagnetic waves without an electrical return path. In one embodiment, for example, the guided wave communication system of the subject disclosure can be configured to induce guided electromagnetic waves that propagate along an outer surface of a coaxial

cable. Although the guided electromagnetic waves will cause forward currents on the ground shield, the guided electromagnetic waves do not require return currents to enable the guided electromagnetic waves to propagate along the outer surface of the coaxial cable. The same can be said of other transmission media used by a guided wave communication system for the transmission and reception of guided electromagnetic waves. For example, guided electromagnetic waves induced by the guided wave communication system on an outer surface of a bare wire, or an insulated wire can propagate along the bare wire or the insulated bare wire without an electrical return path.

Consequently, electrical systems that require two or more conductors for carrying forward and reverse currents on separate conductors to enable the propagation of electrical signals injected by a sending device are distinct from guided wave systems that induce guided electromagnetic waves on an interface of a transmission medium without the need of an electrical return path to enable the propagation of the guided electromagnetic waves along the interface of the transmission medium.

It is further noted that guided electromagnetic waves as described in the subject disclosure can have an electromagnetic field structure that lies primarily or substantially outside of a transmission medium so as to be bound to or guided by the transmission medium and so as to propagate non-trivial distances on or along an outer surface of the transmission medium. In other embodiments, guided electromagnetic waves can have an electromagnetic field structure that lies primarily or substantially inside a transmission medium so as to be bound to or guided by the transmission medium and so as to propagate non-trivial distances within the transmission medium. In other embodiments, guided electromagnetic waves can have an electromagnetic field structure that lies partially inside and partially outside a transmission medium so as to be bound to or guided by the transmission medium and so as to propagate non-trivial distances along the transmission medium. The desired electronic field structure in an embodiment may vary based upon a variety of factors, including the desired transmission distance, the characteristics of the transmission medium itself, and environmental conditions/characteristics outside of the transmission medium (e.g., presence of rain, fog, atmospheric conditions, etc.).

Various embodiments described herein relate to coupling devices, that can be referred to as “waveguide coupling devices”, “waveguide couplers” or more simply as “couplers”, “coupling devices” or “launchers” for launching and/or extracting guided electromagnetic waves to and from a transmission medium at millimeter-wave frequencies (e.g., 30 to 300 GHz), wherein the wavelength can be small compared to one or more dimensions of the coupling device and/or the transmission medium such as the circumference of a wire or other cross sectional dimension, or lower microwave frequencies such as 300 MHz to 30 GHz. Transmissions can be generated to propagate as waves guided by a coupling device, such as: a strip, arc or other length of dielectric material; a horn, monopole, rod, slot or other antenna; an array of antennas; a magnetic resonant cavity, or other resonant coupler; a coil, a strip line, a waveguide or other coupling device. In operation, the coupling device receives an electromagnetic wave from a transmitter or transmission medium. The electromagnetic field structure of the electromagnetic wave can be carried inside the coupling device, outside the coupling device or some combination thereof. When the coupling device is in close proximity to a transmission medium, at least a portion of an electromag-

netic wave couples to or is bound to the transmission medium, and continues to propagate as guided electromagnetic waves. In a reciprocal fashion, a coupling device can extract guided waves from a transmission medium and transfer these electromagnetic waves to a receiver.

According to an example embodiment, a surface wave is a type of guided wave that is guided by a surface of a transmission medium, such as an exterior or outer surface of the wire, or another surface of the wire that is adjacent to or exposed to another type of medium having different properties (e.g., dielectric properties). Indeed, in an example embodiment, a surface of the wire that guides a surface wave can represent a transitional surface between two different types of media. For example, in the case of a bare or uninsulated wire, the surface of the wire can be the outer or exterior conductive surface of the bare or uninsulated wire that is exposed to air or free space. As another example, in the case of insulated wire, the surface of the wire can be the conductive portion of the wire that meets the insulator portion of the wire, or can otherwise be the insulator surface of the wire that is exposed to air or free space, or can otherwise be any material region between the insulator surface of the wire and the conductive portion of the wire that meets the insulator portion of the wire, depending upon the relative differences in the properties (e.g., dielectric properties) of the insulator, air, and/or the conductor and further dependent on the frequency and propagation mode or modes of the guided wave.

According to an example embodiment, the term “about” a wire or other transmission medium used in conjunction with a guided wave can include fundamental guided wave propagation modes such as a guided waves having a circular or substantially circular field distribution, a symmetrical electromagnetic field distribution (e.g., electric field, magnetic field, electromagnetic field, etc.) or other fundamental mode pattern at least partially around a wire or other transmission medium. In addition, when a guided wave propagates “about” a wire or other transmission medium, it can do so according to a guided wave propagation mode that includes not only the fundamental wave propagation modes (e.g., zero order modes), but additionally or alternatively non-fundamental wave propagation modes such as higher-order guided wave modes (e.g.,  $P^{\text{th}}$  order modes,  $2^{\text{nd}}$  order modes, etc.), asymmetrical modes and/or other guided (e.g., surface) waves that have non-circular field distributions around a wire or other transmission medium. As used herein, the term “guided wave mode” refers to a guided wave propagation mode of a transmission medium, coupling device or other system component of a guided wave communication system.

For example, such non-circular field distributions can be unilateral or multi-lateral with one or more axial lobes characterized by relatively higher field strength and/or one or more nulls or null regions characterized by relatively low-field strength, zero-field strength or substantially zero-field strength. Further, the field distribution can otherwise vary as a function of azimuthal orientation around the wire such that one or more angular regions around the wire have an electric or magnetic field strength (or combination thereof) that is higher than one or more other angular regions of azimuthal orientation, according to an example embodiment. It will be appreciated that the relative orientations or positions of the guided wave higher order modes or asymmetrical modes can vary as the guided wave travels along the wire.

As used herein, the term “millimeter-wave” can refer to electromagnetic waves/signals that fall within the “millime-

ter-wave frequency band” of 30 GHz to 300 GHz. The term “microwave” can refer to electromagnetic waves/signals that fall within a “microwave frequency band” of 300 MHz to 300 GHz. The term “radio frequency” or “RF” can refer to electromagnetic waves/signals that fall within the “radio frequency band” of 10 kHz to 1 THz. It is appreciated that wireless signals, electrical signals, and guided electromagnetic waves as described in the subject disclosure can be configured to operate at any desirable frequency range, such as, for example, at frequencies within, above or below millimeter-wave and/or microwave frequency bands. In particular, when a coupling device or transmission medium includes a conductive element, the frequency of the guided electromagnetic waves that are carried by the coupling device and/or propagate along the transmission medium can be below the mean collision frequency of the electrons in the conductive element. Further, the frequency of the guided electromagnetic waves that are carried by the coupling device and/or propagate along the transmission medium can be a non-optical frequency, e.g., a radio frequency below the range of optical frequencies that begins at 1 THz.

As used herein, the term “antenna” can refer to a device that is part of a transmitting or receiving system to transmit/radiate or receive wireless signals.

In accordance with one or more embodiments, a system can include a plurality of mounting brackets connectable with a distal end of a cross member that is fixably attached to a utility pole, where each of the plurality of mounting brackets includes at least one of a plurality of lugs. The system can include a cylindrical member having a curved shape and clamping brackets connecting the cylindrical member with the plurality of lugs. The system can include a mounting carriage connectable with the cylindrical member. The mounting carriage can include an opening for receiving an antenna mount of an antenna. The mounting carriage, when in an unlocked state, can slide via a core bearing along the cylindrical member and can rotate about the core bearing enabling rotation with respect to the cylindrical member. The mounting carriage, when in a locked state, may not slide along the cylindrical member and may not rotate about the core bearing. The antenna, when received in the mounting carriage, can be suspended beyond the distal end of the cross member.

In accordance with one or more embodiments, a method can include connecting a plurality of mounting brackets with a distal end of a cross member that is fixable attached to a utility pole. The method can include connecting a mounting carriage to a curved member and, in turn, connecting the curved member to first and second mounting brackets of the plurality of mounting brackets. The method can include connecting an antenna to the mounting carriage to suspend the antenna beyond the distal ends of the cross member.

In accordance with one or more embodiments, a system can include an antenna comprising a dielectric antenna. Wireless signals can be transmitted by electromagnetic waves that propagate without utilizing an electrical return path, and the electromagnetic waves can be guided by a dielectric core of a cable coupled to a feed point of the dielectric antenna. The system can include a mounting carriage connectable with a mounting bracket. The mounting bracket can be connectable with a cross member of a utility pole. The mounting carriage can include an opening for receiving an antenna mount. When received in the mounting carriage, the antenna can be suspended beyond distal ends of the cross member.

Referring now to FIG. 1, a block diagram **100** illustrating an example, non-limiting embodiment of a guided wave

communications system is shown. In operation, a transmission device **101** receives one or more communication signals **110** from a communication network or other communications device that includes data and generates guided waves **120** to convey the data via the transmission medium **125** to the transmission device **102**. The transmission device **102** receives the guided waves **120** and converts them to communication signals **112** that include the data for transmission to a communications network or other communications device. The guided waves **120** can be modulated to convey data via a modulation technique such as phase shift keying, frequency shift keying, quadrature amplitude modulation, amplitude modulation, multi-carrier modulation such as orthogonal frequency division multiplexing and via multiple access techniques such as frequency division multiplexing, time division multiplexing, code division multiplexing, multiplexing via differing wave propagation modes and via other modulation and access strategies.

The communication network or networks can include a wireless communication network such as a mobile data network, a cellular voice and data network, a wireless local area network (e.g., WiFi or an 802.xx network), a satellite communications network, a personal area network or other wireless network. The communication network or networks can also include a wired communication network such as a telephone network, an Ethernet network, a local area network, a wide area network such as the Internet, a broadband access network, a cable network, a fiber optic network, or other wired network. The communication devices can include a network edge device, bridge device or home gateway, a set-top box, broadband modem, telephone adapter, access point, base station, or other fixed communication device, a mobile communication device such as an automotive gateway or automobile, laptop computer, tablet, smartphone, cellular telephone, or other communication device.

In an example embodiment, the guided wave communication system **100** can operate in a bi-directional fashion where transmission device **102** receives one or more communication signals **112** from a communication network or device that includes other data and generates guided waves **122** to convey the other data via the transmission medium **125** to the transmission device **101**. In this mode of operation, the transmission device **101** receives the guided waves **122** and converts them to communication signals **110** that include the other data for transmission to a communications network or device. The guided waves **122** can be modulated to convey data via a modulation technique such as phase shift keying, frequency shift keying, quadrature amplitude modulation, amplitude modulation, multi-carrier modulation such as orthogonal frequency division multiplexing and via multiple access techniques such as frequency division multiplexing, time division multiplexing, code division multiplexing, multiplexing via differing wave propagation modes and via other modulation and access strategies.

The transmission medium **125** can include a cable having at least one inner portion surrounded by a dielectric material such as an insulator or other dielectric cover, coating or other dielectric material, the dielectric material having an outer surface and a corresponding circumference. In an example embodiment, the transmission medium **125** operates as a single-wire transmission line to guide the transmission of an electromagnetic wave. When the transmission medium **125** is implemented as a single wire transmission system, it can include a wire. The wire can be insulated or uninsulated, and single-stranded or multi-stranded (e.g., braided). In other embodiments, the transmission medium **125** can contain

conductors of other shapes or configurations including wire bundles, cables, rods, rails, pipes. In addition, the transmission medium **125** can include non-conductors such as dielectric pipes, rods, rails, or other dielectric members; combinations of conductors and dielectric materials, conductors without dielectric materials or other guided wave transmission media. It should be noted that the transmission medium **125** can otherwise include any of the transmission media previously discussed.

Further, as previously discussed, the guided waves **120** and **122** can be contrasted with radio transmissions over free space/air or conventional propagation of electrical power or signals through the conductor of a wire via an electrical circuit. In addition to the propagation of guided waves **120** and **122**, the transmission medium **125** may optionally contain one or more wires that propagate electrical power or other communication signals in a conventional manner as a part of one or more electrical circuits.

Referring now to FIG. 2, a block diagram **200** illustrating an example, non-limiting embodiment of a transmission device is shown. The transmission device **101** or **102** includes a communications interface (I/F) **205**, a transceiver **210** and a coupler **220**.

In an example of operation, the communications interface **205** receives a communication signal **110** or **112** that includes data. In various embodiments, the communications interface **205** can include a wireless interface for receiving a wireless communication signal in accordance with a wireless standard protocol such as LTE or other cellular voice and data protocol, WiFi or an 802.11 protocol, WIMAX protocol, Ultra Wideband protocol, Bluetooth protocol, Zigbee protocol, a direct broadcast satellite (DBS) or other satellite communication protocol or other wireless protocol. In addition or in the alternative, the communications interface **205** includes a wired interface that operates in accordance with an Ethernet protocol, universal serial bus (USB) protocol, a data over cable service interface specification (DOCSIS) protocol, a digital subscriber line (DSL) protocol, a Firewire (IEEE 1394) protocol, or other wired protocol. In addition to standards-based protocols, the communications interface **205** can operate in conjunction with other wired or wireless protocol. In addition, the communications interface **205** can optionally operate in conjunction with a protocol stack that includes multiple protocol layers including a MAC protocol, transport protocol, application protocol, etc.

In an example of operation, the transceiver **210** generates an electromagnetic wave based on the communication signal **110** or **112** to convey the data. The electromagnetic wave has at least one carrier frequency and at least one corresponding wavelength. The carrier frequency can be within a millimeter-wave frequency band of 30 GHz-300 GHz, such as 60 GHz or a carrier frequency in the range of 30-40 GHz or a lower frequency band of 300 MHz-30 GHz in the microwave frequency range such as 26-30 GHz, 11 GHz, 6 GHz or 3 GHz, but it will be appreciated that other carrier frequencies are possible in other embodiments. In one mode of operation, the transceiver **210** merely upconverts the communications signal or signals **110** or **112** for transmission of the electromagnetic signal in the microwave or millimeter-wave band as a guided electromagnetic wave that is guided by or bound to the transmission medium **125**. In another mode of operation, the communications interface **205** either converts the communication signal **110** or **112** to a baseband or near baseband signal or extracts the data from the communication signal **110** or **112** and the transceiver **210** modulates a high-frequency carrier with the data, the base-

band or near baseband signal for transmission. It should be appreciated that the transceiver **210** can modulate the data received via the communication signal **110** or **112** to preserve one or more data communication protocols of the communication signal **110** or **112** either by encapsulation in the payload of a different protocol or by simple frequency shifting. In the alternative, the transceiver **210** can otherwise translate the data received via the communication signal **110** or **112** to a protocol that is different from the data communication protocol or protocols of the communication signal **110** or **112**.

In an example of operation, the coupler **220** couples the electromagnetic wave to the transmission medium **125** as a guided electromagnetic wave to convey the communications signal or signals **110** or **112**. While the prior description has focused on the operation of the transceiver **210** as a transmitter, the transceiver **210** can also operate to receive electromagnetic waves that convey other data from the single wire transmission medium via the coupler **220** and to generate communications signals **110** or **112**, via communications interface **205** that includes the other data. Consider embodiments where an additional guided electromagnetic wave conveys other data that also propagates along the transmission medium **125**. The coupler **220** can also couple this additional electromagnetic wave from the transmission medium **125** to the transceiver **210** for reception.

The transmission device **101** or **102** includes an optional training controller **230**. In an example embodiment, the training controller **230** is implemented by a standalone processor or a processor that is shared with one or more other components of the transmission device **101** or **102**. The training controller **230** selects the carrier frequencies, modulation schemes and/or guided wave modes for the guided electromagnetic waves based on feedback data received by the transceiver **210** from at least one remote transmission device coupled to receive the guided electromagnetic wave.

In an example embodiment, a guided electromagnetic wave transmitted by a remote transmission device **101** or **102** conveys data that also propagates along the transmission medium **125**. The data from the remote transmission device **101** or **102** can be generated to include the feedback data. In operation, the coupler **220** also couples the guided electromagnetic wave from the transmission medium **125** and the transceiver receives the electromagnetic wave and processes the electromagnetic wave to extract the feedback data.

In an example embodiment, the training controller **230** operates based on the feedback data to evaluate a plurality of candidate frequencies, modulation schemes and/or transmission modes to select a carrier frequency, modulation scheme and/or transmission mode to enhance performance, such as throughput, signal strength, reduce propagation loss, etc.

Consider the following example: a transmission device **101** begins operation under control of the training controller **230** by sending a plurality of guided waves as test signals such as pilot waves or other test signals at a corresponding plurality of candidate frequencies and/or candidate modes directed to a remote transmission device **102** coupled to the transmission medium **125**. The guided waves can include, in addition or in the alternative, test data. The test data can indicate the particular candidate frequency and/or guide-wave mode of the signal. In an embodiment, the training controller **230** at the remote transmission device **102** receives the test signals and/or test data from any of the guided waves that were properly received and determines the best candidate frequency and/or guided wave mode, a set

of acceptable candidate frequencies and/or guided wave modes, or a rank ordering of candidate frequencies and/or guided wave modes. This selection of candidate frequencies and/or guided-mode(s) are generated by the training controller **230** based on one or more optimizing criteria such as received signal strength, bit error rate, packet error rate, signal to noise ratio, propagation loss, etc. The training controller **230** generates feedback data that indicates the selection of candidate frequency(ies) or/and guided wave mode(s) and sends the feedback data to the transceiver **210** for transmission to the transmission device **101**. The transmission device **101** and **102** can then communicate data with one another based on the selection of candidate frequency(ies) or/and guided wave mode(s).

In other embodiments, the guided electromagnetic waves that contain the test signals and/or test data are reflected back, repeated back or otherwise looped back by the remote transmission device **102** to the transmission device **101** for reception and analysis by the training controller **230** of the transmission device **101** that initiated these waves. For example, the transmission device **101** can send a signal to the remote transmission device **102** to initiate a test mode where a physical reflector is switched on the line, a termination impedance is changed to cause reflections, a loop back mode is switched on to couple electromagnetic waves back to the source transmission device **102**, and/or a repeater mode is enabled to amplify and retransmit the electromagnetic waves back to the source transmission device **102**. The training controller **230** at the source transmission device **102** receives the test signals and/or test data from any of the guided waves that were properly received and determines selection of candidate frequency(ies) or/and guided wave mode(s).

While the procedure above has been described in a start-up or initialization mode of operation, each transmission device **101** or **102** can send test signals, evaluate candidate frequencies or guided wave modes via non-test such as normal transmissions or otherwise evaluate candidate frequencies or guided wave modes at other times or continuously as well. In an example embodiment, the communication protocol between the transmission devices **101** and **102** can include an on-request or periodic test mode where either full testing or more limited testing of a subset of candidate frequencies and guided wave modes are tested and evaluated. In other modes of operation, the re-entry into such a test mode can be triggered by a degradation of performance due to a disturbance, weather conditions, etc. In an example embodiment, the receiver bandwidth of the transceiver **210** is either sufficiently wide or swept to receive all candidate frequencies or can be selectively adjusted by the training controller **230** to a training mode where the receiver bandwidth of the transceiver **210** is sufficiently wide or swept to receive all candidate frequencies.

Referring now to FIG. 3, a graphical diagram **300** illustrating an example, non-limiting embodiment of an electromagnetic field distribution is shown. In this embodiment, a transmission medium **125** in air includes an inner conductor **301** and an insulating jacket **302** of dielectric material, as shown in cross section. The diagram **300** includes different gray-scales that represent differing electromagnetic field strengths generated by the propagation of the guided wave having an asymmetrical and non-fundamental guided wave mode.

In particular, the electromagnetic field distribution corresponds to a modal “sweet spot” that enhances guided electromagnetic wave propagation along an insulated transmission medium and reduces end-to-end transmission loss.

In this particular mode, electromagnetic waves are guided by the transmission medium **125** to propagate along an outer surface of the transmission medium—in this case, the outer surface of the insulating jacket **302**. Electromagnetic waves are partially embedded in the insulator and partially radiating on the outer surface of the insulator. In this fashion, electromagnetic waves are “lightly” coupled to the insulator so as to enable electromagnetic wave propagation at long distances with low propagation loss.

As shown, the guided wave has a field structure that lies primarily or substantially outside of the transmission medium **125** that serves to guide the electromagnetic waves. The regions inside the conductor **301** have little or no field. Likewise regions inside the insulating jacket **302** have low field strength. The majority of the electromagnetic field strength is distributed in the lobes **304** at the outer surface of the insulating jacket **302** and in close proximity thereof. The presence of an asymmetric guided wave mode is shown by the high electromagnetic field strengths at the top and bottom of the outer surface of the insulating jacket **302** (in the orientation of the diagram)—as opposed to very small field strengths on the other sides of the insulating jacket **302**.

The example shown corresponds to a 38 GHz electromagnetic wave guided by a wire with a diameter of 1.1 cm and a dielectric insulation of thickness of 0.36 cm. Because the electromagnetic wave is guided by the transmission medium **125** and the majority of the field strength is concentrated in the air outside of the insulating jacket **302** within a limited distance of the outer surface, the guided wave can propagate longitudinally down the transmission medium **125** with very low loss. In the example shown, this “limited distance” corresponds to a distance from the outer surface that is less than half the largest cross sectional dimension of the transmission medium **125**. In this case, the largest cross sectional dimension of the wire corresponds to the overall diameter of 1.82 cm, however, this value can vary with the size and shape of the transmission medium **125**. For example, should the transmission medium **125** be of a rectangular shape with a height of 0.3 cm and a width of 0.4 cm, the largest cross sectional dimension would be the diagonal of 0.5 cm and the corresponding limited distance would be 0.25 cm. The dimensions of the area containing the majority of the field strength also vary with the frequency, and in general, increase as carrier frequencies decrease.

It should also be noted that the components of a guided wave communication system, such as couplers and transmission media can have their own cut-off frequencies for each guided wave mode. The cut-off frequency generally sets forth the lowest frequency that a particular guided wave mode is designed to be supported by that particular component. In an example embodiment, the particular asymmetric mode of propagation shown is induced on the transmission medium **125** by an electromagnetic wave having a frequency that falls within a limited range (such as  $F_c$  to  $2F_c$ ) of the lower cut-off frequency  $F_c$  for this particular asymmetric mode. The lower cut-off frequency  $F_c$  is particular to the characteristics of transmission medium **125**. For embodiments as shown that include an inner conductor **301** surrounded by an insulating jacket **302**, this cutoff frequency can vary based on the dimensions and properties of the insulating jacket **302** and potentially the dimensions and properties of the inner conductor **301** and can be determined experimentally to have a desired mode pattern. It should be noted however, that similar effects can be found for a hollow dielectric or insulator without an inner conduc-

tor. In this case, the cutoff frequency can vary based on the dimensions and properties of the hollow dielectric or insulator.

At frequencies lower than the lower cut-off frequency, the asymmetric mode is difficult to induce in the transmission medium **125** and fails to propagate for all but trivial distances. As the frequency increases above the limited range of frequencies about the cut-off frequency, the asymmetric mode shifts more and more inward of the insulating jacket **302**. At frequencies much larger than the cut-off frequency, the field strength is no longer concentrated outside of the insulating jacket, but primarily inside of the insulating jacket **302**. While the transmission medium **125** provides strong guidance to the electromagnetic wave and propagation is still possible, ranges are more limited by increased losses due to propagation within the insulating jacket **302**—as opposed to the surrounding air.

Referring now to FIG. 4, a graphical diagram **400** illustrating an example, non-limiting embodiment of an electromagnetic field distribution is shown. In particular, a cross section diagram **400**, similar to FIG. 3 is shown with common reference numerals used to refer to similar elements. The example shown corresponds to a 60 GHz wave guided by a wire with a diameter of 1.1 cm and a dielectric insulation of thickness of 0.36 cm. Because the frequency of the guided wave is above the limited range of the cut-off frequency of this particular asymmetric mode, much of the field strength has shifted inward of the insulating jacket **302**. In particular, the field strength is concentrated primarily inside of the insulating jacket **302**. While the transmission medium **125** provides strong guidance to the electromagnetic wave and propagation is still possible, ranges are more limited when compared with the embodiment of FIG. 3, by increased losses due to propagation within the insulating jacket **302**.

Referring now to FIG. 5A, a graphical diagram illustrating an example, non-limiting embodiment of a frequency response is shown. In particular, diagram **500** presents a graph of end-to-end loss (in dB) as a function of frequency, overlaid with electromagnetic field distributions **510**, **520** and **530** at three points for a 200 cm insulated medium voltage wire. The boundary between the insulator and the surrounding air is represented by reference numeral **525** in each electromagnetic field distribution.

As discussed in conjunction with FIG. 3, an example of a desired asymmetric mode of propagation shown is induced on the transmission medium **125** by an electromagnetic wave having a frequency that falls within a limited range (such as  $F_c$  to  $2F_c$ ) of the lower cut-off frequency  $F_c$  of the transmission medium for this particular asymmetric mode. In particular, the electromagnetic field distribution **520** at 6 GHz falls within this modal “sweet spot” that enhances electromagnetic wave propagation along an insulated transmission medium and reduces end-to-end transmission loss. In this particular mode, guided waves are partially embedded in the insulator and partially radiating on the outer surface of the insulator. In this fashion, the electromagnetic waves are “lightly” coupled to the insulator so as to enable guided electromagnetic wave propagation at long distances with low propagation loss.

At lower frequencies represented by the electromagnetic field distribution **510** at 3 GHz, the asymmetric mode radiates more heavily generating higher propagation losses. At higher frequencies represented by the electromagnetic field distribution **530** at 9 GHz, the asymmetric mode shifts

more and more inward of the insulating jacket providing too much absorption, again generating higher propagation losses.

Referring now to FIG. 5B, a graphical diagram **550** illustrating example, non-limiting embodiments of a longitudinal cross-section of a transmission medium **125**, such as an insulated wire, depicting fields of guided electromagnetic waves at various operating frequencies is shown. As shown in diagram **556**, when the guided electromagnetic waves are at approximately the cutoff frequency ( $f_c$ ) corresponding to the modal “sweet spot”, the guided electromagnetic waves are loosely coupled to the insulated wire so that absorption is reduced, and the fields of the guided electromagnetic waves are bound sufficiently to reduce the amount radiated into the environment (e.g., air). Because absorption and radiation of the fields of the guided electromagnetic waves is low, propagation losses are consequently low, enabling the guided electromagnetic waves to propagate for longer distances.

As shown in diagram **554**, propagation losses increase when an operating frequency of the guide electromagnetic waves increases above about two-times the cutoff frequency ( $f_c$ )—or as referred to, above the range of the “sweet spot”. More of the field strength of the electromagnetic wave is driven inside the insulating layer, increasing propagation losses. At frequencies much higher than the cutoff frequency ( $f_c$ ) the guided electromagnetic waves are strongly bound to the insulated wire as a result of the fields emitted by the guided electromagnetic waves being concentrated in the insulation layer of the wire, as shown in diagram **552**. This in turn raises propagation losses further due to absorption of the guided electromagnetic waves by the insulation layer. Similarly, propagation losses increase when the operating frequency of the guided electromagnetic waves is substantially below the cutoff frequency ( $f_c$ ), as shown in diagram **558**. At frequencies much lower than the cutoff frequency ( $f_c$ ) the guided electromagnetic waves are weakly (or nominally) bound to the insulated wire and thereby tend to radiate into the environment (e.g., air), which in turn, raises propagation losses due to radiation of the guided electromagnetic waves.

Referring now to FIG. 6, a graphical diagram **600** illustrating an example, non-limiting embodiment of an electromagnetic field distribution is shown. In this embodiment, a transmission medium **602** is a bare wire, as shown in cross section. The diagram **300** includes different gray-scales that represent differing electromagnetic field strengths generated by the propagation of a guided wave having a symmetrical and fundamental guided wave mode at a single carrier frequency.

In this particular mode, electromagnetic waves are guided by the transmission medium **602** to propagate along an outer surface of the transmission medium—in this case, the outer surface of the bare wire. Electromagnetic waves are “lightly” coupled to the wire so as to enable electromagnetic wave propagation at long distances with low propagation loss. As shown, the guided wave has a field structure that lies substantially outside of the transmission medium **602** that serves to guide the electromagnetic waves. The regions inside the conductor **602** have little or no field.

Referring now to FIG. 7, a block diagram **700** illustrating an example, non-limiting embodiment of an arc coupler is shown. In particular a coupling device is presented for use in a transmission device, such as transmission device **101** or **102** presented in conjunction with FIG. 1. The coupling device includes an arc coupler **704** coupled to a transmitter circuit **712** and termination or damper **714**. The arc coupler

704 can be made of a dielectric material, or other low-loss insulator (e.g., Teflon, polyethylene, etc.), or made of a conducting (e.g., metallic, non-metallic, etc.) material, or any combination of the foregoing materials. As shown, the arc coupler 704 operates as a waveguide and has a wave 706 propagating as a guided wave about a waveguide surface of the arc coupler 704. In the embodiment shown, at least a portion of the arc coupler 704 can be placed near a wire 702 or other transmission medium, (such as transmission medium 125), in order to facilitate coupling between the arc coupler 704 and the wire 702 or other transmission medium, as described herein to launch the guided wave 708 on the wire. The arc coupler 704 can be placed such that a portion of the curved arc coupler 704 is tangential to, and parallel or substantially parallel to the wire 702. The portion of the arc coupler 704 that is parallel to the wire can be an apex of the curve, or any point where a tangent of the curve is parallel to the wire 702. When the arc coupler 704 is positioned or placed thusly, the wave 706 travelling along the arc coupler 704 couples, at least in part, to the wire 702, and propagates as guided wave 708 around or about the wire surface of the wire 702 and longitudinally along the wire 702. The guided wave 708 can be characterized as a surface wave or other electromagnetic wave that is guided by or bound to the wire 702 or other transmission medium.

A portion of the wave 706 that does not couple to the wire 702 propagates as a wave 710 along the arc coupler 704. It will be appreciated that the arc coupler 704 can be configured and arranged in a variety of positions in relation to the wire 702 to achieve a desired level of coupling or non-coupling of the wave 706 to the wire 702. For example, the curvature and/or length of the arc coupler 704 that is parallel or substantially parallel, as well as its separation distance (which can include zero separation distance in an embodiment), to the wire 702 can be varied without departing from example embodiments. Likewise, the arrangement of arc coupler 704 in relation to the wire 702 may be varied based upon considerations of the respective intrinsic characteristics (e.g., thickness, composition, electromagnetic properties, etc.) of the wire 702 and the arc coupler 704, as well as the characteristics (e.g., frequency, energy level, etc.) of the waves 706 and 708.

The guided wave 708 stays parallel or substantially parallel to the wire 702, even as the wire 702 bends and flexes. Bends in the wire 702 can increase transmission losses, which are also dependent on wire diameters, frequency, and materials. If the dimensions of the arc coupler 704 are chosen for efficient power transfer, most of the power in the wave 706 is transferred to the wire 702, with little power remaining in wave 710. It will be appreciated that the guided wave 708 can still be multi-modal in nature (discussed herein), including having modes that are non-fundamental or asymmetric, while traveling along a path that is parallel or substantially parallel to the wire 702, with or without a fundamental transmission mode. In an embodiment, non-fundamental or asymmetric modes can be utilized to minimize transmission losses and/or obtain increased propagation distances.

It is noted that the term parallel is generally a geometric construct which often is not exactly achievable in real systems. Accordingly, the term parallel as utilized in the subject disclosure represents an approximation rather than an exact configuration when used to describe embodiments disclosed in the subject disclosure. In an embodiment, substantially parallel can include approximations that are within 30 degrees of true parallel in all dimensions.

In an embodiment, the wave 706 can exhibit one or more wave propagation modes. The arc coupler modes can be dependent on the shape and/or design of the coupler 704. The one or more arc coupler modes of wave 706 can generate, influence, or impact one or more wave propagation modes of the guided wave 708 propagating along wire 702. It should be particularly noted however that the guided wave modes present in the guided wave 706 may be the same or different from the guided wave modes of the guided wave 708. In this fashion, one or more guided wave modes of the guided wave 706 may not be transferred to the guided wave 708, and further one or more guided wave modes of guided wave 708 may not have been present in guided wave 706. It should also be noted that the cut-off frequency of the arc coupler 704 for a particular guided wave mode may be different than the cutoff frequency of the wire 702 or other transmission medium for that same mode. For example, while the wire 702 or other transmission medium may be operated slightly above its cutoff frequency for a particular guided wave mode, the arc coupler 704 may be operated well above its cut-off frequency for that same mode for low loss, slightly below its cut-off frequency for that same mode to, for example, induce greater coupling and power transfer, or some other point in relation to the arc coupler's cutoff frequency for that mode.

In an embodiment, the wave propagation modes on the wire 702 can be similar to the arc coupler modes since both waves 706 and 708 propagate about the outside of the arc coupler 704 and wire 702 respectively. In some embodiments, as the wave 706 couples to the wire 702, the modes can change form, or new modes can be created or generated, due to the coupling between the arc coupler 704 and the wire 702. For example, differences in size, material, and/or impedances of the arc coupler 704 and wire 702 may create additional modes not present in the arc coupler modes and/or suppress some of the arc coupler modes. The wave propagation modes can comprise the fundamental transverse electromagnetic mode (Quasi-TEM<sub>00</sub>), where only small electric and/or magnetic fields extend in the direction of propagation, and the electric and magnetic fields extend radially outwards while the guided wave propagates along the wire. This guided wave mode can be donut shaped, where few of the electromagnetic fields exist within the arc coupler 704 or wire 702.

Waves 706 and 708 can comprise a fundamental TEM mode where the fields extend radially outwards, and also comprise other, non-fundamental (e.g., asymmetric, higher-level, etc.) modes. While particular wave propagation modes are discussed above, other wave propagation modes are likewise possible such as transverse electric (TE) and transverse magnetic (TM) modes, based on the frequencies employed, the design of the arc coupler 704, the dimensions and composition of the wire 702, as well as its surface characteristics, its insulation if present, the electromagnetic properties of the surrounding environment, etc. It should be noted that, depending on the frequency, the electrical and physical characteristics of the wire 702 and the particular wave propagation modes that are generated, guided wave 708 can travel along the conductive surface of an oxidized uninsulated wire, an unoxidized uninsulated wire, an insulated wire and/or along the insulating surface of an insulated wire.

In an embodiment, a diameter of the arc coupler 704 is smaller than the diameter of the wire 702. For the millimeter-band wavelength being used, the arc coupler 704 supports a single waveguide mode that makes up wave 706. This single waveguide mode can change as it couples to the

wire **702** as guided wave **708**. If the arc coupler **704** were larger, more than one waveguide mode can be supported, but these additional waveguide modes may not couple to the wire **702** as efficiently, and higher coupling losses can result. However, in some alternative embodiments, the diameter of the arc coupler **704** can be equal to or larger than the diameter of the wire **702**, for example, where higher coupling losses are desirable or when used in conjunction with other techniques to otherwise reduce coupling losses (e.g., impedance matching with tapering, etc.).

In an embodiment, the wavelength of the waves **706** and **708** are comparable in size, or smaller than a circumference of the arc coupler **704** and the wire **702**. In an example, if the wire **702** has a diameter of 0.5 cm, and a corresponding circumference of around 1.5 cm, the wavelength of the transmission is around 1.5 cm or less, corresponding to a frequency of 70 GHz or greater. In another embodiment, a suitable frequency of the transmission and the carrier-wave signal is in the range of 30-100 GHz, perhaps around 30-60 GHz, and around 38 GHz in one example. In an embodiment, when the circumference of the arc coupler **704** and wire **702** is comparable in size to, or greater, than a wavelength of the transmission, the waves **706** and **708** can exhibit multiple wave propagation modes including fundamental and/or non-fundamental (symmetric and/or asymmetric) modes that propagate over sufficient distances to support various communication systems described herein. The waves **706** and **708** can therefore comprise more than one type of electric and magnetic field configuration. In an embodiment, as the guided wave **708** propagates down the wire **702**, the electrical and magnetic field configurations will remain the same from end to end of the wire **702**. In other embodiments, as the guided wave **708** encounters interference (distortion or obstructions) or loses energy due to transmission losses or scattering, the electric and magnetic field configurations can change as the guided wave **708** propagates down wire **702**.

In an embodiment, the arc coupler **704** can be composed of nylon, Teflon, polyethylene, a polyamide, or other plastics. In other embodiments, other dielectric materials are possible. The wire surface of wire **702** can be metallic with either a bare metallic surface, or can be insulated using plastic, dielectric, insulator or other coating, jacket or sheathing. In an embodiment, a dielectric or otherwise non-conducting/insulated waveguide can be paired with either a bare/metallic wire or insulated wire. In other embodiments, a metallic and/or conductive waveguide can be paired with a bare/metallic wire or insulated wire. In an embodiment, an oxidation layer on the bare metallic surface of the wire **702** (e.g., resulting from exposure of the bare metallic surface to oxygen/air) can also provide insulating or dielectric properties similar to those provided by some insulators or sheathings.

It is noted that the graphical representations of waves **706**, **708** and **710** are presented merely to illustrate the principles that wave **706** induces or otherwise launches a guided wave **708** on a wire **702** that operates, for example, as a single wire transmission line. Wave **710** represents the portion of wave **706** that remains on the arc coupler **704** after the generation of guided wave **708**. The actual electric and magnetic fields generated as a result of such wave propagation may vary depending on the frequencies employed, the particular wave propagation mode or modes, the design of the arc coupler **704**, the dimensions and composition of the wire **702**, as well as its surface characteristics, its optional insulation, the electromagnetic properties of the surrounding environment, etc.

It is noted that arc coupler **704** can include a termination circuit or damper **714** at the end of the arc coupler **704** that can absorb leftover radiation or energy from wave **710**. The termination circuit or damper **714** can prevent and/or minimize the leftover radiation or energy from wave **710** reflecting back toward transmitter circuit **712**. In an embodiment, the termination circuit or damper **714** can include termination resistors, and/or other components that perform impedance matching to attenuate reflection. In some embodiments, if the coupling efficiencies are high enough, and/or wave **710** is sufficiently small, it may not be necessary to use a termination circuit or damper **714**. For the sake of simplicity, these transmitter **712** and termination circuits or dampers **714** may not be depicted in the other figures, but in those embodiments, transmitter and termination circuits or dampers may possibly be used.

Further, while a single arc coupler **704** is presented that generates a single guided wave **708**, multiple arc couplers **704** placed at different points along the wire **702** and/or at different azimuthal orientations about the wire can be employed to generate and receive multiple guided waves **708** at the same or different frequencies, at the same or different phases, at the same or different wave propagation modes.

FIG. **8**, a block diagram **800** illustrating an example, non-limiting embodiment of an arc coupler is shown. In the embodiment shown, at least a portion of the coupler **704** can be placed near a wire **702** or other transmission medium, (such as transmission medium **125**), in order to facilitate coupling between the arc coupler **704** and the wire **702** or other transmission medium, to extract a portion of the guided wave **806** as a guided wave **808** as described herein. The arc coupler **704** can be placed such that a portion of the curved arc coupler **704** is tangential to, and parallel or substantially parallel to the wire **702**. The portion of the arc coupler **704** that is parallel to the wire can be an apex of the curve, or any point where a tangent of the curve is parallel to the wire **702**. When the arc coupler **704** is positioned or placed thusly, the wave **806** travelling along the wire **702** couples, at least in part, to the arc coupler **704**, and propagates as guided wave **808** along the arc coupler **704** to a receiving device (not expressly shown). A portion of the wave **806** that does not couple to the arc coupler propagates as wave **810** along the wire **702** or other transmission medium.

In an embodiment, the wave **806** can exhibit one or more wave propagation modes. The arc coupler modes can be dependent on the shape and/or design of the coupler **704**. The one or more modes of guided wave **806** can generate, influence, or impact one or more guide-wave modes of the guided wave **808** propagating along the arc coupler **704**. It should be particularly noted however that the guided wave modes present in the guided wave **806** may be the same or different from the guided wave modes of the guided wave **808**. In this fashion, one or more guided wave modes of the guided wave **806** may not be transferred to the guided wave **808**, and further one or more guided wave modes of guided wave **808** may not have been present in guided wave **806**.

Referring now to FIG. **9A**, a block diagram **900** illustrating an example, non-limiting embodiment of a stub coupler is shown. In particular a coupling device that includes stub coupler **904** is presented for use in a transmission device, such as transmission device **101** or **102** presented in conjunction with FIG. **1**. The stub coupler **904** can be made of a dielectric material, or other low-loss insulator (e.g., Teflon, polyethylene and etc.), or made of a conducting (e.g., metallic, non-metallic, etc.) material, or any combination of

the foregoing materials. As shown, the stub coupler **904** operates as a waveguide and has a wave **906** propagating as a guided wave about a waveguide surface of the stub coupler **904**. In the embodiment shown, at least a portion of the stub coupler **904** can be placed near a wire **702** or other transmission medium, (such as transmission medium **125**), in order to facilitate coupling between the stub coupler **904** and the wire **702** or other transmission medium, as described herein to launch the guided wave **908** on the wire.

In an embodiment, the stub coupler **904** is curved, and an end of the stub coupler **904** can be tied, fastened, or otherwise mechanically coupled to a wire **702**. When the end of the stub coupler **904** is fastened to the wire **702**, the end of the stub coupler **904** is parallel or substantially parallel to the wire **702**. Alternatively, another portion of the dielectric waveguide beyond an end can be fastened or coupled to wire **702** such that the fastened or coupled portion is parallel or substantially parallel to the wire **702**. The fastener **910** can be a nylon cable tie or other type of non-conducting/dielectric material that is either separate from the stub coupler **904** or constructed as an integrated component of the stub coupler **904**. The stub coupler **904** can be adjacent to the wire **702** without surrounding the wire **702**.

Like the arc coupler **704** described in conjunction with FIG. 7, when the stub coupler **904** is placed with the end parallel to the wire **702**, the guided wave **906** travelling along the stub coupler **904** couples to the wire **702**, and propagates as guided wave **908** about the wire surface of the wire **702**. In an example embodiment, the guided wave **908** can be characterized as a surface wave or other electromagnetic wave.

It is noted that the graphical representations of waves **906** and **908** are presented merely to illustrate the principles that wave **906** induces or otherwise launches a guided wave **908** on a wire **702** that operates, for example, as a single wire transmission line. The actual electric and magnetic fields generated as a result of such wave propagation may vary depending on one or more of the shape and/or design of the coupler, the relative position of the dielectric waveguide to the wire, the frequencies employed, the design of the stub coupler **904**, the dimensions and composition of the wire **702**, as well as its surface characteristics, its optional insulation, the electromagnetic properties of the surrounding environment, etc.

In an embodiment, an end of stub coupler **904** can taper towards the wire **702** in order to increase coupling efficiencies. Indeed, the tapering of the end of the stub coupler **904** can provide impedance matching to the wire **702** and reduce reflections, according to an example embodiment of the subject disclosure. For example, an end of the stub coupler **904** can be gradually tapered in order to obtain a desired level of coupling between waves **906** and **908** as illustrated in FIG. 9A.

In an embodiment, the fastener **910** can be placed such that there is a short length of the stub coupler **904** between the fastener **910** and an end of the stub coupler **904**. Maximum coupling efficiencies are realized in this embodiment when the length of the end of the stub coupler **904** that is beyond the fastener **910** is at least several wavelengths long for whatever frequency is being transmitted.

Turning now to FIG. 9B, a diagram **950** illustrating an example, non-limiting embodiment of an electromagnetic distribution in accordance with various aspects described herein is shown. In particular, an electromagnetic distribution is presented in two dimensions for a transmission device that includes coupler **952**, shown in an example stub coupler constructed of a dielectric material. The coupler **952** couples

an electromagnetic wave for propagation as a guided wave along an outer surface of a wire **702** or other transmission medium.

The coupler **952** guides the electromagnetic wave to a junction at  $x_0$  via a symmetrical guided wave mode. While some of the energy of the electromagnetic wave that propagates along the coupler **952** is outside of the coupler **952**, the majority of the energy of this electromagnetic wave is contained within the coupler **952**. The junction at  $x_0$  couples the electromagnetic wave to the wire **702** or other transmission medium at an azimuthal angle corresponding to the bottom of the transmission medium. This coupling induces an electromagnetic wave that is guided to propagate along the outer surface of the wire **702** or other transmission medium via at least one guided wave mode in direction **956**. The majority of the energy of the guided electromagnetic wave is outside or, but in close proximity to the outer surface of the wire **702** or other transmission medium. In the example shown, the junction at  $x_0$  forms an electromagnetic wave that propagates via both a symmetrical mode and at least one asymmetrical surface mode, such as the first order mode presented in conjunction with FIG. 3, that skims the surface of the wire **702** or other transmission medium.

It is noted that the graphical representations of guided waves are presented merely to illustrate an example of guided wave coupling and propagation. The actual electric and magnetic fields generated as a result of such wave propagation may vary depending on the frequencies employed, the design and/or configuration of the coupler **952**, the dimensions and composition of the wire **702** or other transmission medium, as well as its surface characteristics, its insulation if present, the electromagnetic properties of the surrounding environment, etc.

Turning now to FIG. 10A, illustrated is a block diagram **1000** of an example, non-limiting embodiment of a coupler and transceiver system in accordance with various aspects described herein. The system is an example of transmission device **101** or **102**. In particular, the communication interface **1008** is an example of communications interface **205**, the stub coupler **1002** is an example of coupler **220**, and the transmitter/receiver device **1006**, diplexer **1016**, power amplifier **1014**, low noise amplifier **1018**, frequency mixers **1010** and **1020** and local oscillator **1012** collectively form an example of transceiver **210**.

In operation, the transmitter/receiver device **1006** launches and receives waves (e.g., guided wave **1004** onto stub coupler **1002**). The guided waves **1004** can be used to transport signals received from and sent to a host device, base station, mobile devices, a building or other device by way of a communications interface **1008**. The communications interface **1008** can be an integral part of system **1000**. Alternatively, the communications interface **1008** can be tethered to system **1000**. The communications interface **1008** can comprise a wireless interface for interfacing to the host device, base station, mobile devices, a building or other device utilizing any of various wireless signaling protocols (e.g., LTE, WiFi, WiMAX, IEEE 802.xx, etc.) including an infrared protocol such as an infrared data association (IrDA) protocol or other line of sight optical protocol. The communications interface **1008** can also comprise a wired interface such as a fiber optic line, coaxial cable, twisted pair, category 5 (CAT-5) cable or other suitable wired or optical mediums for communicating with the host device, base station, mobile devices, a building or other device via a protocol such as an Ethernet protocol, universal serial bus (USB) protocol, a data over cable service interface specification (DOCSIS) protocol, a digital subscriber line (DSL)

protocol, a Firewire (IEEE 1394) protocol, or other wired or optical protocol. For embodiments where system 1000 functions as a repeater, the communications interface 1008 may not be necessary.

The output signals (e.g., Tx) of the communications interface 1008 can be combined with a carrier wave (e.g., millimeter-wave carrier wave) generated by a local oscillator 1012 at frequency mixer 1010. Frequency mixer 1010 can use heterodyning techniques or other frequency shifting techniques to frequency shift the output signals from communications interface 1008. For example, signals sent to and from the communications interface 1008 can be modulated signals such as orthogonal frequency division multiplexed (OFDM) signals formatted in accordance with a Long-Term Evolution (LTE) wireless protocol or other wireless 3G, 4G, 5G or higher voice and data protocol, a Zigbee, WIMAX, UltraWideband or IEEE 802.11 wireless protocol; a wired protocol such as an Ethernet protocol, universal serial bus (USB) protocol, a data over cable service interface specification (DOCSIS) protocol, a digital subscriber line (DSL) protocol, a Firewire (IEEE 1394) protocol or other wired or wireless protocol. In an example embodiment, this frequency conversion can be done in the analog domain, and as a result, the frequency shifting can be done without regard to the type of communications protocol used by a base station, mobile devices, or in-building devices. As new communications technologies are developed, the communications interface 1008 can be upgraded (e.g., updated with software, firmware, and/or hardware) or replaced and the frequency shifting and transmission apparatus can remain, simplifying upgrades. The carrier wave can then be sent to a power amplifier (“PA”) 1014 and can be transmitted via the transmitter/receiver device 1006 via the diplexer 1016.

Signals received from the transmitter/receiver device 1006 that are directed towards the communications interface 1008 can be separated from other signals via diplexer 1016. The received signal can then be sent to low noise amplifier (“LNA”) 1018 for amplification. A frequency mixer 1020, with help from local oscillator 1012 can downshift the received signal (which is in the millimeter-wave band or around 38 GHz in some embodiments) to the native frequency. The communications interface 1008 can then receive the transmission at an input port (Rx).

In an embodiment, transmitter/receiver device 1006 can include a cylindrical or non-cylindrical metal (which, for example, can be hollow in an embodiment, but not necessarily drawn to scale) or other conducting or non-conducting waveguide and an end of the stub coupler 1002 can be placed in or in proximity to the waveguide or the transmitter/receiver device 1006 such that when the transmitter/receiver device 1006 generates a transmission, the guided wave couples to stub coupler 1002 and propagates as a guided wave 1004 about the waveguide surface of the stub coupler 1002. In some embodiments, the guided wave 1004 can propagate in part on the outer surface of the stub coupler 1002 and in part inside the stub coupler 1002. In other embodiments, the guided wave 1004 can propagate substantially or completely on the outer surface of the stub coupler 1002. In yet other embodiments, the guided wave 1004 can propagate substantially or completely inside the stub coupler 1002. In this latter embodiment, the guided wave 1004 can radiate at an end of the stub coupler 1002 (such as the tapered end shown in FIG. 4) for coupling to a transmission medium such as a wire 702 of FIG. 7. Similarly, if guided wave 1004 is incoming (coupled to the stub coupler 1002 from a wire 702), guided wave 1004 then enters the transmitter/receiver device 1006 and couples to the cylindrical

waveguide or conducting waveguide. While transmitter/receiver device 1006 is shown to include a separate waveguide—an antenna, cavity resonator, klystron, magnetron, travelling wave tube, or other radiating element can be employed to induce a guided wave on the coupler 1002, with or without the separate waveguide.

In an embodiment, stub coupler 1002 can be wholly constructed of a dielectric material (or another suitable insulating material), without any metallic or otherwise conducting materials therein. Stub coupler 1002 can be composed of nylon, Teflon, polyethylene, a polyamide, other plastics, or other materials that are non-conducting and suitable for facilitating transmission of electromagnetic waves at least in part on an outer surface of such materials. In another embodiment, stub coupler 1002 can include a core that is conducting/metallic, and have an exterior dielectric surface. Similarly, a transmission medium that couples to the stub coupler 1002 for propagating electromagnetic waves induced by the stub coupler 1002 or for supplying electromagnetic waves to the stub coupler 1002 can, in addition to being a bare or insulated wire, be wholly constructed of a dielectric material (or another suitable insulating material), without any metallic or otherwise conducting materials therein.

It is noted that although FIG. 10A shows that the opening of transmitter/receiver device 1006 is much wider than the stub coupler 1002, this is not to scale, and that in other embodiments the width of the stub coupler 1002 is comparable or slightly smaller than the opening of the hollow waveguide. It is also not shown, but in an embodiment, an end of the coupler 1002 that is inserted into the transmitter/receiver device 1006 tapers down in order to reduce reflection and increase coupling efficiencies.

Before coupling to the stub coupler 1002, the one or more waveguide modes of the guided wave generated by the transmitter/receiver device 1006 can couple to the stub coupler 1002 to induce one or more wave propagation modes of the guided wave 1004. The wave propagation modes of the guided wave 1004 can be different than the hollow metal waveguide modes due to the different characteristics of the hollow metal waveguide and the dielectric waveguide. For instance, wave propagation modes of the guided wave 1004 can comprise the fundamental transverse electromagnetic mode (Quasi-TEM<sub>00</sub>), where only small electrical and/or magnetic fields extend in the direction of propagation, and the electric and magnetic fields extend radially outwards from the stub coupler 1002 while the guided waves propagate along the stub coupler 1002. The fundamental transverse electromagnetic mode wave propagation mode may or may not exist inside a waveguide that is hollow. Therefore, the hollow metal waveguide modes that are used by transmitter/receiver device 1006 are waveguide modes that can couple effectively and efficiently to wave propagation modes of stub coupler 1002.

It will be appreciated that other constructs or combinations of the transmitter/receiver device 1006 and stub coupler 1002 are possible. For example, a stub coupler 1002' can be placed tangentially or in parallel (with or without a gap) with respect to an outer surface of the hollow metal waveguide of the transmitter/receiver device 1006' (corresponding circuitry not shown) as depicted by reference 1000' of FIG. 10B. In another embodiment, not shown by reference 1000', the stub coupler 1002' can be placed inside the hollow metal waveguide of the transmitter/receiver device 1006' without an axis of the stub coupler 1002' being coaxially aligned with an axis of the hollow metal waveguide of the transmitter/receiver device 1006'. In either of these embodi-

ments, the guided wave generated by the transmitter/receiver device **1006'** can couple to a surface of the stub coupler **1002'** to induce one or more wave propagation modes of the guided wave **1004'** on the stub coupler **1002'** including a fundamental mode (e.g., a symmetric mode) and/or a non-fundamental mode (e.g., asymmetric mode).

In one embodiment, the guided wave **1004'** can propagate in part on the outer surface of the stub coupler **1002'** and in part inside the stub coupler **1002'**. In another embodiment, the guided wave **1004'** can propagate substantially or completely on the outer surface of the stub coupler **1002'**. In yet other embodiments, the guided wave **1004'** can propagate substantially or completely inside the stub coupler **1002'**. In this latter embodiment, the guided wave **1004'** can radiate at an end of the stub coupler **1002'** (such as the tapered end shown in FIG. 9) for coupling to a transmission medium such as a wire **702** of FIG. 9.

It will be further appreciated that other constructs the transmitter/receiver device **1006** are possible. For example, a hollow metal waveguide of a transmitter/receiver device **1006''** (corresponding circuitry not shown), depicted in FIG. 10B as reference **1000''**, can be placed tangentially or in parallel (with or without a gap) with respect to an outer surface of a transmission medium such as the wire **702** of FIG. 4 without the use of the stub coupler **1002**. In this embodiment, the guided wave generated by the transmitter/receiver device **1006''** can couple to a surface of the wire **702** to induce one or more wave propagation modes of a guided wave **908** on the wire **702** including a fundamental mode (e.g., a symmetric mode) and/or a non-fundamental mode (e.g., asymmetric mode). In another embodiment, the wire **702** can be positioned inside a hollow metal waveguide of a transmitter/receiver device **1006'''** (corresponding circuitry not shown) so that an axis of the wire **702** is coaxially (or not coaxially) aligned with an axis of the hollow metal waveguide without the use of the stub coupler **1002**—see FIG. 10B reference **1000'''**. In this embodiment, the guided wave generated by the transmitter/receiver device **1006'''** can couple to a surface of the wire **702** to induce one or more wave propagation modes of a guided wave **908** on the wire including a fundamental mode (e.g., a symmetric mode) and/or a non-fundamental mode (e.g., asymmetric mode).

In the embodiments of **1000''** and **1000'''**, for a wire **702** having an insulated outer surface, the guided wave **908** can propagate in part on the outer surface of the insulator and in part inside the insulator. In embodiments, the guided wave **908** can propagate substantially or completely on the outer surface of the insulator, or substantially or completely inside the insulator. In the embodiments of **1000''** and **1000'''**, for a wire **702** that is a bare conductor, the guided wave **908** can propagate in part on the outer surface of the conductor and in part inside the conductor. In another embodiment, the guided wave **908** can propagate substantially or completely on the outer surface of the conductor.

Referring now to FIG. 11, a block diagram **1100** illustrating an example, non-limiting embodiment of a dual stub coupler is shown. In particular, a dual coupler design is presented for use in a transmission device, such as transmission device **101** or **102** presented in conjunction with FIG. 1. In an embodiment, two or more couplers (such as the stub couplers **1104** and **1106**) can be positioned around a wire **1102** in order to receive guided wave **1108**. In an embodiment, one coupler is enough to receive the guided wave **1108**. In that case, guided wave **1108** couples to coupler **1104** and propagates as guided wave **1110**. If the field structure of the guided wave **1108** oscillates or undulates around the wire **1102** due to the particular guided wave

mode(s) or various outside factors, then coupler **1106** can be placed such that guided wave **1108** couples to coupler **1106**. In some embodiments, four or more couplers can be placed around a portion of the wire **1102**, e.g., at 90 degrees or another spacing with respect to each other, in order to receive guided waves that may oscillate or rotate around the wire **1102**, that have been induced at different azimuthal orientations or that have non-fundamental or higher order modes that, for example, have lobes and/or nulls or other asymmetries that are orientation dependent. However, it will be appreciated that there may be less than or more than four couplers placed around a portion of the wire **1102** without departing from example embodiments.

It should be noted that while couplers **1106** and **1104** are illustrated as stub couplers, any other of the coupler designs described herein including arc couplers, antenna or horn couplers, magnetic couplers, etc., could likewise be used. It will also be appreciated that while some example embodiments have presented a plurality of couplers around at least a portion of a wire **1102**, this plurality of couplers can also be considered as part of a single coupler system having multiple coupler subcomponents. For example, two or more couplers can be manufactured as single system that can be installed around a wire in a single installation such that the couplers are either pre-positioned or adjustable relative to each other (either manually or automatically with a controllable mechanism such as a motor or other actuator) in accordance with the single system.

Receivers coupled to couplers **1106** and **1104** can use diversity combining to combine signals received from both couplers **1106** and **1104** in order to maximize the signal quality. In other embodiments, if one or the other of the couplers **1104** and **1106** receive a transmission that is above a predetermined threshold, receivers can use selection diversity when deciding which signal to use. Further, while reception by a plurality of couplers **1106** and **1104** is illustrated, transmission by couplers **1106** and **1104** in the same configuration can likewise take place. In particular, a wide range of multi-input multi-output (MIMO) transmission and reception techniques can be employed for transmissions where a transmission device, such as transmission device **101** or **102** presented in conjunction with FIG. 1 includes multiple transceivers and multiple couplers.

It is noted that the graphical representations of waves **1108** and **1110** are presented merely to illustrate the principles that guided wave **1108** induces or otherwise launches a wave **1110** on a coupler **1104**. The actual electric and magnetic fields generated as a result of such wave propagation may vary depending on the frequencies employed, the design of the coupler **1104**, the dimensions and composition of the wire **1102**, as well as its surface characteristics, its insulation if any, the electromagnetic properties of the surrounding environment, etc.

Referring now to FIG. 12, a block diagram **1200** illustrating an example, non-limiting embodiment of a repeater system is shown. In particular, a repeater device **1210** is presented for use in a transmission device, such as transmission device **101** or **102** presented in conjunction with FIG. 1. In this system, two couplers **1204** and **1214** can be placed near a wire **1202** or other transmission medium such that guided waves **1205** propagating along the wire **1202** are extracted by coupler **1204** as wave **1206** (e.g. as a guided wave), and then are boosted or repeated by repeater device **1210** and launched as a wave **1216** (e.g. as a guided wave) onto coupler **1214**. The wave **1216** can then be launched on the wire **1202** and continue to propagate along the wire **1202** as a guided wave **1217**. In an embodiment, the repeater

device **1210** can receive at least a portion of the power utilized for boosting or repeating through magnetic coupling with the wire **1202**, for example, when the wire **1202** is a power line or otherwise contains a power-carrying conductor. It should be noted that while couplers **1204** and **1214** are illustrated as stub couplers, any other of the coupler designs described herein including arc couplers, antenna or horn couplers, magnetic couplers, or the like, could likewise be used.

In some embodiments, repeater device **1210** can repeat the transmission associated with wave **1206**, and in other embodiments, repeater device **1210** can include a communications interface **205** that extracts data or other signals from the wave **1206** for supplying such data or signals to another network and/or one or more other devices as communication signals **110** or **112** and/or receiving communication signals **110** or **112** from another network and/or one or more other devices and launch guided wave **1216** having embedded therein the received communication signals **110** or **112**. In a repeater configuration, receiver waveguide **1208** can receive the wave **1206** from the coupler **1204** and transmitter waveguide **1212** can launch guided wave **1216** onto coupler **1214** as guided wave **1217**. Between receiver waveguide **1208** and transmitter waveguide **1212**, the signal embedded in guided wave **1206** and/or the guided wave **1216** itself can be amplified to correct for signal loss and other inefficiencies associated with guided wave communications or the signal can be received and processed to extract the data contained therein and regenerated for transmission. In an embodiment, the receiver waveguide **1208** can be configured to extract data from the signal, process the data to correct for data errors utilizing for example error correcting codes, and regenerate an updated signal with the corrected data. The transmitter waveguide **1212** can then transmit guided wave **1216** with the updated signal embedded therein. In an embodiment, a signal embedded in guided wave **1206** can be extracted from the transmission and processed for communication with another network and/or one or more other devices via communications interface **205** as communication signals **110** or **112**. Similarly, communication signals **110** or **112** received by the communications interface **205** can be inserted into a transmission of guided wave **1216** that is generated and launched onto coupler **1214** by transmitter waveguide **1212**.

It is noted that although FIG. **12** shows guided wave transmissions **1206** and **1216** entering from the left and exiting to the right respectively, this is merely a simplification and is not intended to be limiting. In other embodiments, receiver waveguide **1208** and transmitter waveguide **1212** can also function as transmitters and receivers respectively, allowing the repeater device **1210** to be bi-directional.

In an embodiment, repeater device **1210** can be placed at locations where there are discontinuities or obstacles on the wire **1202** or other transmission medium. In the case where the wire **1202** is a power line, these obstacles can include transformers, connections, utility poles, and other such power line devices. The repeater device **1210** can help the guided (e.g., surface) waves jump over these obstacles on the line and boost the transmission power at the same time. In other embodiments, a coupler can be used to jump over the obstacle without the use of a repeater device. In that embodiment, both ends of the coupler can be tied or fastened to the wire, thus providing a path for the guided wave to travel without being blocked by the obstacle.

Turning now to FIG. **13**, illustrated is a block diagram **1300** of an example, non-limiting embodiment of a bidirectional repeater in accordance with various aspects described

herein. In particular, a bidirectional repeater device **1306** is presented for use in a transmission device, such as transmission device **101** or **102** presented in conjunction with FIG. **1**. It should be noted that while the couplers are illustrated as stub couplers, any other of the coupler designs described herein including arc couplers, antenna or horn couplers, magnetic couplers, or the like, could likewise be used. The bidirectional repeater **1306** can employ diversity paths in the case of when two or more wires or other transmission media are present. Since guided wave transmissions have different transmission efficiencies and coupling efficiencies for transmission medium of different types such as insulated wires, un-insulated wires or other types of transmission media and further, if exposed to the elements, can be affected by weather, and other atmospheric conditions, it can be advantageous to selectively transmit on different transmission media at certain times. In various embodiments, the various transmission media can be designated as a primary, secondary, tertiary, etc. whether or not such designation indicates a preference of one transmission medium over another.

In the embodiment shown, the transmission media include an insulated or uninsulated wire **1302** and an insulated or uninsulated wire **1304** (referred to herein as wires **1302** and **1304**, respectively). The repeater device **1306** uses a receiver coupler **1308** to receive a guided wave traveling along wire **1302** and repeats the transmission using transmitter waveguide **1310** as a guided wave along wire **1304**. In other embodiments, repeater device **1306** can switch from the wire **1304** to the wire **1302**, or can repeat the transmissions along the same paths. Repeater device **1306** can include sensors, or be in communication with sensors (or a network management system **1601** depicted in FIG. **16A**) that indicate conditions that can affect the transmission. Based on the feedback received from the sensors, the repeater device **1306** can make the determination about whether to keep the transmission along the same wire, or transfer the transmission to the other wire.

Turning now to FIG. **14**, illustrated is a block diagram **1400** illustrating an example, non-limiting embodiment of a bidirectional repeater system. In particular, a bidirectional repeater system is presented for use in a transmission device, such as transmission device **101** or **102** presented in conjunction with FIG. **1**. The bidirectional repeater system includes waveguide coupling devices **1402** and **1404** that receive and transmit transmissions from other coupling devices located in a distributed antenna system or backhaul system.

In various embodiments, waveguide coupling device **1402** can receive a transmission from another waveguide coupling device, wherein the transmission has a plurality of subcarriers. Diplexer **1406** can separate the transmission from other transmissions, and direct the transmission to low-noise amplifier (“LNA”) **1408**. A frequency mixer **1428**, with help from a local oscillator **1412**, can downshift the transmission (which is in the millimeter-wave band or around 38 GHz in some embodiments) to a lower frequency, such as a cellular band (~1.9 GHz) for a distributed antenna system, a native frequency, or other frequency for a backhaul system. An extractor (or demultiplexer) **1432** can extract the signal on a subcarrier and direct the signal to an output component **1422** for optional amplification, buffering or isolation by power amplifier **1424** for coupling to communications interface **205**. The communications interface **205** can further process the signals received from the power amplifier **1424** or otherwise transmit such signals over a wireless or wired interface to other devices such as a base

station, mobile devices, a building, etc. For the signals that are not being extracted at this location, extractor **1432** can redirect them to another frequency mixer **1436**, where the signals are used to modulate a carrier wave generated by local oscillator **1414**. The carrier wave, with its subcarriers, is directed to a power amplifier (“PA”) **1416** and is retransmitted by waveguide coupling device **1404** to another system, via diplexer **1420**.

An LNA **1426** can be used to amplify, buffer or isolate signals that are received by the communication interface **205** and then send the signal to a multiplexer **1434** which merges the signal with signals that have been received from waveguide coupling device **1404**. The signals received from coupling device **1404** have been split by diplexer **1420**, and then passed through LNA **1418**, and downshifted in frequency by frequency mixer **1438**. When the signals are combined by multiplexer **1434**, they are upshifted in frequency by frequency mixer **1430**, and then boosted by PA **1410**, and transmitted to another system by waveguide coupling device **1402**. In an embodiment bidirectional repeater system can be merely a repeater without the output device **1422**. In this embodiment, the multiplexer **1434** would not be utilized and signals from LNA **1418** would be directed to mixer **1430** as previously described. It will be appreciated that in some embodiments, the bidirectional repeater system could also be implemented using two distinct and separate unidirectional repeaters. In an alternative embodiment, a bidirectional repeater system could also be a booster or otherwise perform retransmissions without downshifting and upshifting. Indeed in example embodiment, the retransmissions can be based upon receiving a signal or guided wave and performing some signal or guided wave processing or reshaping, filtering, and/or amplification, prior to retransmission of the signal or guided wave.

Referring now to FIG. **15**, a block diagram **1500** illustrating an example, non-limiting embodiment of a guided wave communications system is shown. This diagram depicts an exemplary environment in which a guided wave communication system, such as the guided wave communication system presented in conjunction with FIG. **1**, can be used.

To provide network connectivity to additional base station devices, a backhaul network that links the communication cells (e.g., macrocells and macrocells) to network devices of a core network correspondingly expands. Similarly, to provide network connectivity to a distributed antenna system, an extended communication system that links base station devices and their distributed antennas is desirable. A guided wave communication system **1500** such as shown in FIG. **15** can be provided to enable alternative, increased or additional network connectivity and a waveguide coupling system can be provided to transmit and/or receive guided wave (e.g., surface wave) communications on a transmission medium such as a wire that operates as a single-wire transmission line (e.g., a utility line), and that can be used as a waveguide and/or that otherwise operates to guide the transmission of an electromagnetic wave.

The guided wave communication system **1500** can comprise a first instance of a distribution system **1550** that includes one or more base station devices (e.g., base station device **1504**) that are communicably coupled to a central office **1501** and/or a macrocell site **1502**. Base station device **1504** can be connected by a wired (e.g., fiber and/or cable), or by a wireless (e.g., microwave wireless) connection to the macrocell site **1502** and the central office **1501**. A second instance of the distribution system **1560** can be used to provide wireless voice and data services to mobile device

**1522** and to residential and/or commercial establishments **1542** (herein referred to as establishments **1542**). System **1500** can have additional instances of the distribution systems **1550** and **1560** for providing voice and/or data services to mobile devices **1522-1524** and establishments **1542** as shown in FIG. **15**.

Macrocells such as macrocell site **1502** can have dedicated connections to a mobile network and base station device **1504** or can share and/or otherwise use another connection. Central office **1501** can be used to distribute media content and/or provide internet service provider (ISP) services to mobile devices **1522-1524** and establishments **1542**. The central office **1501** can receive media content from a constellation of satellites **1530** (one of which is shown in FIG. **15**) or other sources of content, and distribute such content to mobile devices **1522-1524** and establishments **1542** via the first and second instances of the distribution system **1550** and **1560**. The central office **1501** can also be communicatively coupled to the Internet **1503** for providing internet data services to mobile devices **1522-1524** and establishments **1542**.

Base station device **1504** can be mounted on, or attached to, utility pole **1516**. In other embodiments, base station device **1504** can be near transformers and/or other locations situated nearby a power line. Base station device **1504** can facilitate connectivity to a mobile network for mobile devices **1522** and **1524**. Antennas **1512** and **1514**, mounted on or near utility poles **1518** and **1520**, respectively, can receive signals from base station device **1504** and transmit those signals to mobile devices **1522** and **1524** over a much wider area than if the antennas **1512** and **1514** were located at or near base station device **1504**.

It is noted that FIG. **15** displays three utility poles, in each instance of the distribution systems **1550** and **1560**, with one base station device, for purposes of simplicity. In other embodiments, utility pole **1516** can have more base station devices, and more utility poles with distributed antennas and/or tethered connections to establishments **1542**.

A transmission device **1506**, such as transmission device **101** or **102** presented in conjunction with FIG. **1**, can transmit a signal from base station device **1504** to antennas **1512** and **1514** via utility or power line(s) that connect the utility poles **1516**, **1518**, and **1520**. The transmission device **1506** can be mounted in various ways with the utility pole **1516**, such as on a cross-member or cross-tree **1599**, including at an end of the cross-tree. To transmit the signal, radio source and/or transmission device **1506** upconverts the signal (e.g., via frequency mixing) from base station device **1504** or otherwise converts the signal from the base station device **1504** to a microwave band signal and the transmission device **1506** launches a microwave band wave that propagates as a guided wave traveling along the utility line or other wire as described in previous embodiments. At utility pole **1518**, another transmission device **1508** receives the guided wave (and optionally can amplify it as needed or desired or operate as a repeater to receive it and regenerate it) and sends it forward as a guided wave on the utility line or other wire. The transmission device **1508** can also extract a signal from the microwave band guided wave and shift it down in frequency or otherwise convert it to its original cellular band frequency (e.g., 1.9 GHz or other defined cellular frequency) or another cellular (or non-cellular) band frequency. An antenna **1512** can wireless transmit the downshifted signal to mobile device **1522**. The process can be repeated by transmission device **1510**, antenna **1514** and mobile device **1524**, as necessary or desirable.

Transmissions from mobile devices **1522** and **1524** can also be received by antennas **1512** and **1514** respectively. The transmission devices **1508** and **1510** can upshift or otherwise convert the cellular band signals to microwave band and transmit the signals as guided wave (e.g., surface wave or other electromagnetic wave) transmissions over the power line(s) to base station device **1504**.

Media content received by the central office **1501** can be supplied to the second instance of the distribution system **1560** via the base station device **1504** for distribution to mobile devices **1522** and establishments **1542**. The transmission device **1510** can be tethered to the establishments **1542** by one or more wired connections or a wireless interface. The one or more wired connections may include without limitation, a power line, a coaxial cable, a fiber cable, a twisted pair cable, a guided wave transmission medium or other suitable wired mediums for distribution of media content and/or for providing internet services. In an example embodiment, the wired connections from the transmission device **1510** can be communicatively coupled to one or more very high bit rate digital subscriber line (VDSL) modems located at one or more corresponding service area interfaces (SAIs—not shown) or pedestals, each SAI or pedestal providing services to a portion of the establishments **1542**. The VDSL modems can be used to selectively distribute media content and/or provide internet services to gateways (not shown) located in the establishments **1542**. The SAI or pedestals can also be communicatively coupled to the establishments **1542** over a wired medium such as a power line, a coaxial cable, a fiber cable, a twisted pair cable, a guided wave transmission medium or other suitable wired mediums. In other example embodiments, the transmission device **1510** can be communicatively coupled directly to establishments **1542** without intermediate interfaces such as the SAI or pedestals.

In another example embodiment, system **1500** can employ diversity paths, where two or more utility lines or other wires are strung between the utility poles **1516**, **1518**, and **1520** (e.g., for example, two or more wires between poles **1516** and **1520**) and redundant transmissions from base station/macrocell site **1502** are transmitted as guided waves down the surface of the utility lines or other wires. The utility lines or other wires can be either insulated or uninsulated, and depending on the environmental conditions that cause transmission losses, the coupling devices can selectively receive signals from the insulated or uninsulated utility lines or other wires. The selection can be based on measurements of the signal-to-noise ratio of the wires, or based on determined weather/environmental conditions (e.g., moisture detectors, weather forecasts, etc.). The use of diversity paths with system **1500** can enable alternate routing capabilities, load balancing, increased load handling, concurrent bi-directional or synchronous communications, spread spectrum communications, etc.

It is noted that the use of the transmission devices **1506**, **1508**, and **1510** in FIG. **15** are by way of example only, and that in other embodiments, other uses are possible. For instance, transmission devices can be used in a backhaul communication system, providing network connectivity to base station devices. Transmission devices **1506**, **1508**, and **1510** can be used in many circumstances where it is desirable to transmit guided wave communications over a wire, whether insulated or not insulated. Transmission devices **1506**, **1508**, and **1510** are improvements over other coupling devices due to no contact or limited physical and/or electrical contact with the wires that may carry high voltages. The transmission device can be located away from the wire

(e.g., spaced apart from the wire) and/or located on the wire so long as it is not electrically in contact with the wire, as the dielectric acts as an insulator, allowing for cheap, easy, and/or less complex installation. However, as previously noted conducting or non-dielectric couplers can be employed, for example in configurations where the wires correspond to a telephone network, cable television network, broadband data service, fiber optic communications system or other network employing low voltages or having insulated transmission lines.

It is further noted, that while base station device **1504** and macrocell site **1502** are illustrated in an embodiment, other network configurations are likewise possible. For example, devices such as access points or other wireless gateways can be employed in a similar fashion to extend the reach of other networks such as a wireless local area network, a wireless personal area network or other wireless network that operates in accordance with a communication protocol such as a 802.11 protocol, WIMAX protocol, UltraWideband protocol, Bluetooth protocol, Zigbee protocol or other wireless protocol.

Referring now to FIGS. **16A** & **16B**, block diagrams illustrating an example, non-limiting embodiment of a system for managing a power grid communication system are shown. Considering FIG. **16A**, a waveguide system **1602** is presented for use in a guided wave communications system, such as the system presented in conjunction with FIG. **15**. The waveguide system **1602** can comprise sensors **1604**, a power management system **1605**, a transmission device **101** or **102** that includes at least one communication interface **205**, transceiver **210** and coupler **220**.

The waveguide system **1602** can be coupled to a power line **1610** for facilitating guided wave communications in accordance with embodiments described in the subject disclosure. In an example embodiment, the transmission device **101** or **102** includes coupler **220** for inducing electromagnetic waves on a surface of the power line **1610** that longitudinally propagate along the surface of the power line **1610** as described in the subject disclosure. The transmission device **101** or **102** can also serve as a repeater for retransmitting electromagnetic waves on the same power line **1610** or for routing electromagnetic waves between power lines **1610** as shown in FIGS. **12-13**.

The transmission device **101** or **102** includes transceiver **210** configured to, for example, up-convert a signal operating at an original frequency range to electromagnetic waves operating at, exhibiting, or associated with a carrier frequency that propagate along a coupler to induce corresponding guided electromagnetic waves that propagate along a surface of the power line **1610**. A carrier frequency can be represented by a center frequency having upper and lower cutoff frequencies that define the bandwidth of the electromagnetic waves. The power line **1610** can be a wire (e.g., single stranded or multi-stranded) having a conducting surface or insulated surface. The transceiver **210** can also receive signals from the coupler **220** and down-convert the electromagnetic waves operating at a carrier frequency to signals at their original frequency.

Signals received by the communications interface **205** of transmission device **101** or **102** for up-conversion can include without limitation signals supplied by a central office **1611** over a wired or wireless interface of the communications interface **205**, a base station **1614** over a wired or wireless interface of the communications interface **205**, wireless signals transmitted by mobile devices **1620** to the base station **1614** for delivery over the wired or wireless interface of the communications interface **205**, signals sup-

plied by in-building communication devices **1618** over the wired or wireless interface of the communications interface **205**, and/or wireless signals supplied to the communications interface **205** by mobile devices **1612** roaming in a wireless communication range of the communications interface **205**. In embodiments where the waveguide system **1602** functions as a repeater, such as shown in FIGS. **12-13**, the communications interface **205** may or may not be included in the waveguide system **1602**.

The electromagnetic waves propagating along the surface of the power line **1610** can be modulated and formatted to include packets or frames of data that include a data payload and further include networking information (such as header information for identifying one or more destination waveguide systems **1602**). The networking information may be provided by the waveguide system **1602** or an originating device such as the central office **1611**, the base station **1614**, mobile devices **1620**, or in-building devices **1618**, or a combination thereof. Additionally, the modulated electromagnetic waves can include error correction data for mitigating signal disturbances. The networking information and error correction data can be used by a destination waveguide system **1602** for detecting transmissions directed to it, and for down-converting and processing with error correction data transmissions that include voice and/or data signals directed to recipient communication devices communicatively coupled to the destination waveguide system **1602**.

Referring now to the sensors **1604** of the waveguide system **1602**, the sensors **1604** can comprise one or more of a temperature sensor **1604a**, a disturbance detection sensor **1604b**, a loss of energy sensor **1604c**, a noise sensor **1604d**, a vibration sensor **1604e**, an environmental (e.g., weather) sensor **1604f**, and/or an image sensor **1604g**. The temperature sensor **1604a** can be used to measure ambient temperature, a temperature of the transmission device **101** or **102**, a temperature of the power line **1610**, temperature differentials (e.g., compared to a setpoint or baseline, between transmission device **101** or **102** and **1610**, etc.), or any combination thereof. In one embodiment, temperature metrics can be collected and reported periodically to a network management system **1601** by way of the base station **1614**.

The disturbance detection sensor **1604b** can perform measurements on the power line **1610** to detect disturbances such as signal reflections, which may indicate a presence of a downstream disturbance that may impede the propagation of electromagnetic waves on the power line **1610**. A signal reflection can represent a distortion resulting from, for example, an electromagnetic wave transmitted on the power line **1610** by the transmission device **101** or **102** that reflects in whole or in part back to the transmission device **101** or **102** from a disturbance in the power line **1610** located downstream from the transmission device **101** or **102**.

Signal reflections can be caused by obstructions on the power line **1610**. For example, a tree limb may cause electromagnetic wave reflections when the tree limb is lying on the power line **1610**, or is in close proximity to the power line **1610** which may cause a corona discharge. Other obstructions that can cause electromagnetic wave reflections can include without limitation an object that has been entangled on the power line **1610** (e.g., clothing, a shoe wrapped around a power line **1610** with a shoe string, etc.), a corroded build-up on the power line **1610** or an ice build-up. Power grid components may also impede or obstruct with the propagation of electromagnetic waves on the surface of power lines **1610**. Illustrations of power grid components that may cause signal reflections include without limitation a transformer and a joint for connecting

spliced power lines. A sharp angle on the power line **1610** may also cause electromagnetic wave reflections.

The disturbance detection sensor **1604b** can comprise a circuit to compare magnitudes of electromagnetic wave reflections to magnitudes of original electromagnetic waves transmitted by the transmission device **101** or **102** to determine how much a downstream disturbance in the power line **1610** attenuates transmissions. The disturbance detection sensor **1604b** can further comprise a spectral analyzer circuit for performing spectral analysis on the reflected waves. The spectral data generated by the spectral analyzer circuit can be compared with spectral profiles via pattern recognition, an expert system, curve fitting, matched filtering or other artificial intelligence, classification or comparison technique to identify a type of disturbance based on, for example, the spectral profile that most closely matches the spectral data. The spectral profiles can be stored in a memory of the disturbance detection sensor **1604b** or may be remotely accessible by the disturbance detection sensor **1604b**. The profiles can comprise spectral data that models different disturbances that may be encountered on power lines **1610** to enable the disturbance detection sensor **1604b** to identify disturbances locally. An identification of the disturbance if known can be reported to the network management system **1601** by way of the base station **1614**. The disturbance detection sensor **1604b** can also utilize the transmission device **101** or **102** to transmit electromagnetic waves as test signals to determine a roundtrip time for an electromagnetic wave reflection. The round trip time measured by the disturbance detection sensor **1604b** can be used to calculate a distance traveled by the electromagnetic wave up to a point where the reflection takes place, which enables the disturbance detection sensor **1604b** to calculate a distance from the transmission device **101** or **102** to the downstream disturbance on the power line **1610**.

The distance calculated can be reported to the network management system **1601** by way of the base station **1614**. In one embodiment, the location of the waveguide system **1602** on the power line **1610** may be known to the network management system **1601**, which the network management system **1601** can use to determine a location of the disturbance on the power line **1610** based on a known topology of the power grid. In another embodiment, the waveguide system **1602** can provide its location to the network management system **1601** to assist in the determination of the location of the disturbance on the power line **1610**. The location of the waveguide system **1602** can be obtained by the waveguide system **1602** from a pre-programmed location of the waveguide system **1602** stored in a memory of the waveguide system **1602**, or the waveguide system **1602** can determine its location using a GPS receiver (not shown) included in the waveguide system **1602**.

The power management system **1605** provides energy to the aforementioned components of the waveguide system **1602**. The power management system **1605** can receive energy from solar cells, or from a transformer (not shown) coupled to the power line **1610**, or by inductive coupling to the power line **1610** or another nearby power line. The power management system **1605** can also include a backup battery and/or a super capacitor or other capacitor circuit for providing the waveguide system **1602** with temporary power. The loss of energy sensor **1604c** can be used to detect when the waveguide system **1602** has a loss of power condition and/or the occurrence of some other malfunction. For example, the loss of energy sensor **1604c** can detect when there is a loss of power due to defective solar cells, an obstruction on the solar cells that causes them to malfunc-

tion, loss of power on the power line **1610**, and/or when the backup power system malfunctions due to expiration of a backup battery, or a detectable defect in a super capacitor. When a malfunction and/or loss of power occurs, the loss of energy sensor **1604c** can notify the network management system **1601** by way of the base station **1614**.

The noise sensor **1604d** can be used to measure noise on the power line **1610** that may adversely affect transmission of electromagnetic waves on the power line **1610**. The noise sensor **1604d** can sense unexpected electromagnetic interference, noise bursts, or other sources of disturbances that may interrupt reception of modulated electromagnetic waves on a surface of a power line **1610**. A noise burst can be caused by, for example, a corona discharge, or other source of noise. The noise sensor **1604d** can compare the measured noise to a noise profile obtained by the waveguide system **1602** from an internal database of noise profiles or from a remotely located database that stores noise profiles via pattern recognition, an expert system, curve fitting, matched filtering or other artificial intelligence, classification or comparison technique. From the comparison, the noise sensor **1604d** may identify a noise source (e.g., corona discharge or otherwise) based on, for example, the noise profile that provides the closest match to the measured noise. The noise sensor **1604d** can also detect how noise affects transmissions by measuring transmission metrics such as bit error rate, packet loss rate, jitter, packet retransmission requests, etc. The noise sensor **1604d** can report to the network management system **1601** by way of the base station **1614** the identity of noise sources, their time of occurrence, and transmission metrics, among other things.

The vibration sensor **1604e** can include accelerometers and/or gyroscopes to detect 2D or 3D vibrations on the power line **1610**. The vibrations can be compared to vibration profiles that can be stored locally in the waveguide system **1602**, or obtained by the waveguide system **1602** from a remote database via pattern recognition, an expert system, curve fitting, matched filtering or other artificial intelligence, classification or comparison technique. Vibration profiles can be used, for example, to distinguish fallen trees from wind gusts based on, for example, the vibration profile that provides the closest match to the measured vibrations. The results of this analysis can be reported by the vibration sensor **1604e** to the network management system **1601** by way of the base station **1614**.

The environmental sensor **1604f** can include a barometer for measuring atmospheric pressure, ambient temperature (which can be provided by the temperature sensor **1604a**), wind speed, humidity, wind direction, and rainfall, among other things. The environmental sensor **1604f** can collect raw information and process this information by comparing it to environmental profiles that can be obtained from a memory of the waveguide system **1602** or a remote database to predict weather conditions before they arise via pattern recognition, an expert system, knowledge-based system or other artificial intelligence, classification or other weather modeling and prediction technique. The environmental sensor **1604f** can report raw data as well as its analysis to the network management system **1601**.

The image sensor **1604g** can be a digital camera (e.g., a charged coupled device or CCD imager, infrared camera, etc.) for capturing images in a vicinity of the waveguide system **1602**. The image sensor **1604g** can include an electromechanical mechanism to control movement (e.g., actual position or focal points/zooms) of the camera for inspecting the power line **1610** from multiple perspectives (e.g., top surface, bottom surface, left surface, right surface

and so on). Alternatively, the image sensor **1604g** can be designed such that no electromechanical mechanism is needed in order to obtain the multiple perspectives. The collection and retrieval of imaging data generated by the image sensor **1604g** can be controlled by the network management system **1601**, or can be autonomously collected and reported by the image sensor **1604g** to the network management system **1601**.

Other sensors that may be suitable for collecting telemetry information associated with the waveguide system **1602** and/or the power lines **1610** for purposes of detecting, predicting and/or mitigating disturbances that can impede the propagation of electromagnetic wave transmissions on power lines **1610** (or any other form of a transmission medium of electromagnetic waves) may be utilized by the waveguide system **1602**.

Referring now to FIG. **16B**, block diagram **1650** illustrates an example, non-limiting embodiment of a system for managing a power grid **1653** and a communication system **1655** embedded therein or associated therewith in accordance with various aspects described herein. The communication system **1655** comprises a plurality of waveguide systems **1602** coupled to power lines **1610** of the power grid **1653**. At least a portion of the waveguide systems **1602** used in the communication system **1655** can be in direct communication with a base station **1614** and/or the network management system **1601**. Waveguide systems **1602** not directly connected to a base station **1614** or the network management system **1601** can engage in communication sessions with either a base station **1614** or the network management system **1601** by way of other downstream waveguide systems **1602** connected to a base station **1614** or the network management system **1601**.

The network management system **1601** can be communicatively coupled to equipment of a utility company **1652** and equipment of a communications service provider **1654** for providing each entity, status information associated with the power grid **1653** and the communication system **1655**, respectively. The network management system **1601**, the equipment of the utility company **1652**, and the communications service provider **1654** can access communication devices utilized by utility company personnel **1656** and/or communication devices utilized by communications service provider personnel **1658** for purposes of providing status information and/or for directing such personnel in the management of the power grid **1653** and/or communication system **1655**.

FIG. **17A** illustrates a flow diagram of an example, non-limiting embodiment of a method **1700** for detecting and mitigating disturbances occurring in a communication network of the systems of FIGS. **16A** & **16B**. Method **1700** can begin with step **1702** where a waveguide system **1602** transmits and receives messages embedded in, or forming part of, modulated electromagnetic waves or another type of electromagnetic waves traveling along a surface of a power line **1610**. The messages can be voice messages, streaming video, and/or other data/information exchanged between communication devices communicatively coupled to the communication system **1655**. At step **1704** the sensors **1604** of the waveguide system **1602** can collect sensing data. In an embodiment, the sensing data can be collected in step **1704** prior to, during, or after the transmission and/or receipt of messages in step **1702**. At step **1706** the waveguide system **1602** (or the sensors **1604** themselves) can determine from the sensing data an actual or predicted occurrence of a disturbance in the communication system **1655** that can affect communications originating from (e.g., transmitted

by) or received by the waveguide system **1602**. The waveguide system **1602** (or the sensors **1604**) can process temperature data, signal reflection data, loss of energy data, noise data, vibration data, environmental data, or any combination thereof to make this determination. The waveguide system **1602** (or the sensors **1604**) may also detect, identify, estimate, or predict the source of the disturbance and/or its location in the communication system **1655**. If a disturbance is neither detected/identified nor predicted/estimated at step **1708**, the waveguide system **1602** can proceed to step **1702** where it continues to transmit and receive messages embedded in, or forming part of, modulated electromagnetic waves traveling along a surface of the power line **1610**.

If at step **1708** a disturbance is detected/identified or predicted/estimated to occur, the waveguide system **1602** proceeds to step **1710** to determine if the disturbance adversely affects (or alternatively, is likely to adversely affect or the extent to which it may adversely affect) transmission or reception of messages in the communication system **1655**. In one embodiment, a duration threshold and a frequency of occurrence threshold can be used at step **1710** to determine when a disturbance adversely affects communications in the communication system **1655**. For illustration purposes only, assume a duration threshold is set to 500 ms, while a frequency of occurrence threshold is set to 5 disturbances occurring in an observation period of 10 sec. Thus, a disturbance having a duration greater than 500 ms will trigger the duration threshold. Additionally, any disturbance occurring more than 5 times in a 10 sec time interval will trigger the frequency of occurrence threshold.

In one embodiment, a disturbance may be considered to adversely affect signal integrity in the communication systems **1655** when the duration threshold alone is exceeded. In another embodiment, a disturbance may be considered as adversely affecting signal integrity in the communication systems **1655** when both the duration threshold and the frequency of occurrence threshold are exceeded. The latter embodiment is thus more conservative than the former embodiment for classifying disturbances that adversely affect signal integrity in the communication system **1655**. It will be appreciated that many other algorithms and associated parameters and thresholds can be utilized for step **1710** in accordance with example embodiments.

Referring back to method **1700**, if at step **1710** the disturbance detected at step **1708** does not meet the condition for adversely affected communications (e.g., neither exceeds the duration threshold nor the frequency of occurrence threshold), the waveguide system **1602** may proceed to step **1702** and continue processing messages. For instance, if the disturbance detected in step **1708** has a duration of 1 msec with a single occurrence in a 10 sec time period, then neither threshold will be exceeded. Consequently, such a disturbance may be considered as having a nominal effect on signal integrity in the communication system **1655** and thus would not be flagged as a disturbance requiring mitigation. Although not flagged, the occurrence of the disturbance, its time of occurrence, its frequency of occurrence, spectral data, and/or other useful information, may be reported to the network management system **1601** as telemetry data for monitoring purposes.

Referring back to step **1710**, if on the other hand the disturbance satisfies the condition for adversely affected communications (e.g., exceeds either or both thresholds), the waveguide system **1602** can proceed to step **1712** and report the incident to the network management system **1601**. The report can include raw sensing data collected by the sensors **1604**, a description of the disturbance if known by the

waveguide system **1602**, a time of occurrence of the disturbance, a frequency of occurrence of the disturbance, a location associated with the disturbance, parameters readings such as bit error rate, packet loss rate, retransmission requests, jitter, latency and so on. If the disturbance is based on a prediction by one or more sensors of the waveguide system **1602**, the report can include a type of disturbance expected, and if predictable, an expected time occurrence of the disturbance, and an expected frequency of occurrence of the predicted disturbance when the prediction is based on historical sensing data collected by the sensors **1604** of the waveguide system **1602**.

At step **1714**, the network management system **1601** can determine a mitigation, circumvention, or correction technique, which may include directing the waveguide system **1602** to reroute traffic to circumvent the disturbance if the location of the disturbance can be determined. In one embodiment, the waveguide coupling device **1402** detecting the disturbance may direct a repeater such as the one shown in FIGS. **13-14** to connect the waveguide system **1602** from a primary power line affected by the disturbance to a secondary power line to enable the waveguide system **1602** to reroute traffic to a different transmission medium and avoid the disturbance. In an embodiment where the waveguide system **1602** is configured as a repeater the waveguide system **1602** can itself perform the rerouting of traffic from the primary power line to the secondary power line. It is further noted that for bidirectional communications (e.g., full or half-duplex communications), the repeater can be configured to reroute traffic from the secondary power line back to the primary power line for processing by the waveguide system **1602**.

In another embodiment, the waveguide system **1602** can redirect traffic by instructing a first repeater situated upstream of the disturbance and a second repeater situated downstream of the disturbance to redirect traffic from a primary power line temporarily to a secondary power line and back to the primary power line in a manner that avoids the disturbance. It is further noted that for bidirectional communications (e.g., full or half-duplex communications), repeaters can be configured to reroute traffic from the secondary power line back to the primary power line.

To avoid interrupting existing communication sessions occurring on a secondary power line, the network management system **1601** may direct the waveguide system **1602** to instruct repeater(s) to utilize unused time slot(s) and/or frequency band(s) of the secondary power line for redirecting data and/or voice traffic away from the primary power line to circumvent the disturbance.

At step **1716**, while traffic is being rerouted to avoid the disturbance, the network management system **1601** can notify equipment of the utility company **1652** and/or equipment of the communications service provider **1654**, which in turn may notify personnel of the utility company **1656** and/or personnel of the communications service provider **1658** of the detected disturbance and its location if known. Field personnel from either party can attend to resolving the disturbance at a determined location of the disturbance. Once the disturbance is removed or otherwise mitigated by personnel of the utility company and/or personnel of the communications service provider, such personnel can notify their respective companies and/or the network management system **1601** utilizing field equipment (e.g., a laptop computer, smartphone, etc.) communicatively coupled to network management system **1601**, and/or equipment of the utility company and/or the communications service provider. The notification can include a description of how the

disturbance was mitigated and any changes to the power lines **1610** that may change a topology of the communication system **1655**.

Once the disturbance has been resolved (as determined in decision **1718**), the network management system **1601** can direct the waveguide system **1602** at step **1720** to restore the previous routing configuration used by the waveguide system **1602** or route traffic according to a new routing configuration if the restoration strategy used to mitigate the disturbance resulted in a new network topology of the communication system **1655**. In another embodiment, the waveguide system **1602** can be configured to monitor mitigation of the disturbance by transmitting test signals on the power line **1610** to determine when the disturbance has been removed. Once the waveguide system **1602** detects an absence of the disturbance it can autonomously restore its routing configuration without assistance by the network management system **1601** if it determines the network topology of the communication system **1655** has not changed, or it can utilize a new routing configuration that adapts to a detected new network topology.

FIG. 17B illustrates a flow diagram of an example, non-limiting embodiment of a method **1750** for detecting and mitigating disturbances occurring in a communication network of the system of FIGS. 16A and 16B. In one embodiment, method **1750** can begin with step **1752** where a network management system **1601** receives from equipment of the utility company **1652** or equipment of the communications service provider **1654** maintenance information associated with a maintenance schedule. The network management system **1601** can at step **1754** identify from the maintenance information, maintenance activities to be performed during the maintenance schedule. From these activities, the network management system **1601** can detect a disturbance resulting from the maintenance (e.g., scheduled replacement of a power line **1610**, scheduled replacement of a waveguide system **1602** on the power line **1610**, scheduled reconfiguration of power lines **1610** in the power grid **1653**, etc.).

In another embodiment, the network management system **1601** can receive at step **1755** telemetry information from one or more waveguide systems **1602**. The telemetry information can include among other things an identity of each waveguide system **1602** submitting the telemetry information, measurements taken by sensors **1604** of each waveguide system **1602**, information relating to predicted, estimated, or actual disturbances detected by the sensors **1604** of each waveguide system **1602**, location information associated with each waveguide system **1602**, an estimated location of a detected disturbance, an identification of the disturbance, and so on. The network management system **1601** can determine from the telemetry information a type of disturbance that may be adverse to operations of the waveguide, transmission of the electromagnetic waves along the wire surface, or both. The network management system **1601** can also use telemetry information from multiple waveguide systems **1602** to isolate and identify the disturbance. Additionally, the network management system **1601** can request telemetry information from waveguide systems **1602** in a vicinity of an affected waveguide system **1602** to triangulate a location of the disturbance and/or validate an identification of the disturbance by receiving similar telemetry information from other waveguide systems **1602**.

In yet another embodiment, the network management system **1601** can receive at step **1756** an unscheduled activity report from maintenance field personnel. Unscheduled maintenance may occur as result of field calls that are

unplanned or as a result of unexpected field issues discovered during field calls or scheduled maintenance activities. The activity report can identify changes to a topology configuration of the power grid **1653** resulting from field personnel addressing discovered issues in the communication system **1655** and/or power grid **1653**, changes to one or more waveguide systems **1602** (such as replacement or repair thereof), mitigation of disturbances performed if any, and so on.

At step **1758**, the network management system **1601** can determine from reports received according to steps **1752** through **1756** if a disturbance will occur based on a maintenance schedule, or if a disturbance has occurred or is predicted to occur based on telemetry data, or if a disturbance has occurred due to an unplanned maintenance identified in a field activity report. From any of these reports, the network management system **1601** can determine whether a detected or predicted disturbance requires rerouting of traffic by the affected waveguide systems **1602** or other waveguide systems **1602** of the communication system **1655**.

When a disturbance is detected or predicted at step **1758**, the network management system **1601** can proceed to step **1760** where it can direct one or more waveguide systems **1602** to reroute traffic to circumvent the disturbance. When the disturbance is permanent due to a permanent topology change of the power grid **1653**, the network management system **1601** can proceed to step **1770** and skip steps **1762**, **1764**, **1766**, and **1772**. At step **1770**, the network management system **1601** can direct one or more waveguide systems **1602** to use a new routing configuration that adapts to the new topology. However, when the disturbance has been detected from telemetry information supplied by one or more waveguide systems **1602**, the network management system **1601** can notify maintenance personnel of the utility company **1656** or the communications service provider **1658** of a location of the disturbance, a type of disturbance if known, and related information that may be helpful to such personnel to mitigate the disturbance. When a disturbance is expected due to maintenance activities, the network management system **1601** can direct one or more waveguide systems **1602** to reconfigure traffic routes at a given schedule (consistent with the maintenance schedule) to avoid disturbances caused by the maintenance activities during the maintenance schedule.

Returning back to step **1760** and upon its completion, the process can continue with step **1762**. At step **1762**, the network management system **1601** can monitor when the disturbance(s) have been mitigated by field personnel. Mitigation of a disturbance can be detected at step **1762** by analyzing field reports submitted to the network management system **1601** by field personnel over a communications network (e.g., cellular communication system) utilizing field equipment (e.g., a laptop computer or handheld computer/device). If field personnel have reported that a disturbance has been mitigated, the network management system **1601** can proceed to step **1764** to determine from the field report whether a topology change was required to mitigate the disturbance. A topology change can include rerouting a power line **1610**, reconfiguring a waveguide system **1602** to utilize a different power line **1610**, otherwise utilizing an alternative link to bypass the disturbance and so on. If a topology change has taken place, the network management system **1601** can direct at step **1770** one or more waveguide systems **1602** to use a new routing configuration that adapts to the new topology.

If, however, a topology change has not been reported by field personnel, the network management system **1601** can

proceed to step **1766** where it can direct one or more waveguide systems **1602** to send test signals to test a routing configuration that had been used prior to the detected disturbance(s). Test signals can be sent to affected waveguide systems **1602** in a vicinity of the disturbance. The test signals can be used to determine if signal disturbances (e.g., electromagnetic wave reflections) are detected by any of the waveguide systems **1602**. If the test signals confirm that a prior routing configuration is no longer subject to previously detected disturbance(s), then the network management system **1601** can at step **1772** direct the affected waveguide systems **1602** to restore a previous routing configuration. If, however, test signals analyzed by one or more waveguide coupling device **1402** and reported to the network management system **1601** indicate that the disturbance(s) or new disturbance(s) are present, then the network management system **1601** will proceed to step **1768** and report this information to field personnel to further address field issues. The network management system **1601** can in this situation continue to monitor mitigation of the disturbance(s) at step **1762**.

In the aforementioned embodiments, the waveguide systems **1602** can be configured to be self-adapting to changes in the power grid **1653** and/or to mitigation of disturbances. That is, one or more affected waveguide systems **1602** can be configured to self-monitor mitigation of disturbances and reconfigure traffic routes without requiring instructions to be sent to them by the network management system **1601**. In this embodiment, the one or more waveguide systems **1602** that are self-configurable can inform the network management system **1601** of its routing choices so that the network management system **1601** can maintain a macro-level view of the communication topology of the communication system **1655**.

While for purposes of simplicity of explanation, the respective processes are shown and described as a series of blocks in FIGS. **17A** and **17B**, respectively, it is to be understood and appreciated that the claimed subject matter is not limited by the order of the blocks, as some blocks may occur in different orders and/or concurrently with other blocks from what is depicted and described herein. Moreover, not all illustrated blocks may be required to implement the methods described herein.

Turning now to FIG. **18**, a system **1800** is illustrated which enables mounting of network devices with respect to particular support structure, such as a utility pole **1830** which can have various shapes, sizes and/or be made from various materials. System **1800** can function as a mounting structure to support various network devices, including point-to-point wireless antennas, electronics, 5G radio modules, waveguides, dielectric antennas, and so forth. System **1800** can be secured on a wide range of metal and wooden light and power poles (or other structure), such as those that are commonly found in streets, parking lots, public spaces and other locations. System **1800** enables adjustments of an alignment of an antenna(s), such as direction, spacing, elevation and/or azimuth, and further enables mounting to a wide range of pole diameters, and shapes ranging from round to square, straight wall and tapered.

System **1800** includes various components that facilitate assembly and connection to the utility pole **1830**, requiring reduced or minimal precision in assembly placement. When fully assembled, the system **1800** can provide a stable and rigid platform that can also endure temperature cycling, such as without loosening and slippage. As an example, system **1800** can include a plurality of mounting brackets **1810** (four of which are shown) that are connectable with the utility

pole **1830**. Various structure and techniques can be utilized for connecting the mounting brackets **1810** with the utility pole **1830**, including screws and so forth. In one embodiment, pairs of the mounting brackets **1810** can hold or otherwise be connected with a cylindrical member **1840**, such as a rolled pipe (two of which are shown). For example, the cylindrical member **1840** can have a curved shape that at least partially circumscribes the utility pole **1830**. In one embodiment, clamping brackets **1820** can be utilized to connect the cylindrical member **1840** with a plurality of lugs **1825** that are each connected with a different one of the mounting brackets **1810**.

In one or more embodiments, a mounting carriage **1860** can be connected with the cylindrical member **1840**. For example, the mounting carriage **1860** can include an opening for receiving an antenna mount of an antenna (not shown) which when in an unlocked state allows the antenna to be rotated and which when in a locked state does not allow the antenna to be rotated. In one embodiment, the mounting carriage **1860** when in an unlocked state can slide along the cylindrical member **1860** as shown by arrow **1861** and/or when in an unlocked state can rotate about the cylindrical member as shown by arrow **1862**. When the mounting carriage **1860** is in a locked state, it does not slide along the cylindrical member **1840** and/or does not rotate about the cylindrical member. The use of locked and unlocked states allows the mounting carriage and the antenna to be manually adjusted, such as during installation.

System **1800** illustrates two cylindrical members **1840** resulting in circumscribing the utility pole **1830** by about 240 degrees. Any number of cylindrical members **1840** can be utilized (which can be of any length including a 90 degree arc or more or less than a 90 degree arc) which fully or only partially circumscribe the utility pole **1830**.

Referring to FIG. **19**, a system **1900** is illustrated which enables mounting of network devices with respect to particular support structure, such as a utility pole **1930** which can have various shapes, sizes (e.g., a larger diameter pole is shown in the dashed line **1931**) and/or be made from various materials. System **1900** can be utilized with one or more components described in system **1800**. In one embodiment, system **1900** includes mounting brackets **1910** that are connectable with the utility pole **1930** and which include cylindrical members **1940** that fully circumscribe the utility pole. In another embodiment, the mounting brackets **1910** are connectable with the utility pole **1931** and the cylindrical member **1940** only partially circumscribes the utility pole. The mounting brackets **1910** can have a tapered inner face to facilitate mating or abutting against a non-flat surface, such as a round utility pole.

In one embodiment, clamping brackets **1920** can be utilized to connect the cylindrical members **1940** with the mounting brackets **1910** via clamping openings **1922** in the clamping brackets. In another embodiment, the clamping brackets **1920** can be positioned over each other (i.e., stacked) and connected with the same lug of a plurality of lugs **1925** that are each connected with a different one of the mounting brackets **1910**. FIG. **19** illustrates in one or more embodiments that different diameter poles can be accommodated by this assembly by the sliding of the arced cylindrical member **1940** through clamp opening **1922**. The length of the arc of cylindrical member **1940** engaged between the two clamping brackets **1920** will then vary according to the diameter of the pole **1830**. Note that clamping bracket **1920** in one or more embodiments will rotate around lug **1925** to accommodate its changing angle of engagement with **1940** when mounted to a smaller

diameter pole **1830**. The adaptable arrangement of these mounting and clamping brackets and the arced cylindrical member can then be utilized to clamp around different sized poles by these accommodations of items **1940**, **1920**.

In one or more embodiments, an antenna mount of the antenna (not shown) when in an unlocked state rotates about an opening in the mounting carriage, where the antenna mount when in a locked state does not rotate about the opening in the mounting carriage. In one or more embodiments, the mounting carriage includes a carriage core therethrough, where a core bearing is positioned in the carriage core, and where the mounting carriage when in the unlocked state rotates about the cylindrical member **1940** based on the mounting carriage rotating about the core bearing without the core bearing rotating about the cylindrical member. In one or more embodiments, the core bearing is not coaxially aligned with the cylindrical member **1940**. In one or more embodiments, the carriage member includes a first securing member (e.g., one or more screws) for adjusting between the unlocked state and the locked state of the mounting carriage; and a second securing member (e.g., one or more screws) for adjusting between the unlocked state and the locked state of the antenna mount. In one or more embodiments, an adjustable strap (not shown) can be connected with each of the plurality of mounting brackets **1910**, such as to facilitate the installation process. In one or more embodiments, each of the plurality of lugs **1925** can be pivotally connected with one of the plurality of mounting brackets **1910**.

Referring to FIG. **20**, a system **2000** is illustrated which enables mounting of network devices with respect to particular support structure, such as a utility pole **2030** which can have various shapes, sizes and/or be made from various materials. System **2000** can be utilized with one or more components described in systems **1800**, **1900**. In one or more embodiments, an inter-bracket plate **2080** can be connected with adjacent pairs of the plurality of mounting brackets **2010**. The inter-bracket plate can be adapted (e.g., holes or other mounting structure) to allow for connection of an electronics module **2085** thereto. In one or more embodiments, the electronics module **2085** can enable wireless communications via an antenna (not shown). In one or more embodiments, the electronics module **2085** can facilitate transmitting wireless communications and can include various components such as one or more of a transmitter, receiver, transceiver, filter(s), and so forth. In one or more embodiments, the electronics module **2085** can facilitate obtaining power from a power line coupled with the utility pole **2030** and can include various components such as a battery, a power regulator, inductive coupling circuit, and so forth.

Referring to FIG. **21**, a system **2100** is illustrated which enables mounting of network devices with respect to particular support structure, such as a utility pole **2130** which in this example has a square shape. System **2100** can be utilized with one or more components described in systems **1800**, **1900**, **2000**. For instance, an inner face **2115** of the mounting brackets **2110** can be configured or otherwise shaped to abut against or otherwise receive a corner **2135** of the square utility pole **2130**. In one embodiment, the inner face **2115** can be tapered at a selected angle to facilitate mating the corner **2135** of the square utility pole **2130** with the mounting bracket **2110**. Various structure and techniques can be utilized for connecting the mounting brackets **2110** with the utility pole **2130**, including screws and so forth.

In one or more embodiments, an inter-bracket plate **2180** can be connected with adjacent pairs of the plurality of mounting brackets **2110**, where the inter-bracket plate con-

nects an electronics module **2185** thereto, and where the electronics module enables wireless communications via an antenna (not shown).

Referring to FIGS. **22-31**, a system **2200** is illustrated which enables mounting of network devices with respect to particular support structure, such as a utility pole **2230** which can have various shapes, sizes and/or be made from various materials. System **2200** can be utilized with one or more components described in systems **1800**, **1900**, **2000**, **2100**. System **2200** provides a stable platform for the additional assembly or support of one or more elevation and azimuth adjusting mounts (e.g., mounting carriage **2260** connected along cylindrical member **2240** which is secured to mounting brackets **2210** as shown in FIG. **22**) that are adapted to accept an antenna **2290**, such as a point-to-point mm Wave antenna, sub-millimeter-wave radio antenna or FSOC optical link. As an example, the mounting carriage **2260** can include a securing mechanism **2295** for receiving and securing an antenna mount **2292** of the antenna **2290**. System **2200** enables selectively spacing and orientating of multiple antennas **2290** at the utility pole **2230**.

When assembled, the pointing direction for the antenna **2290** can be manually adjusted, such as through use of a built-in bore-sighting tube described herein. In this example, once manually adjusted to a desired position/direction, the antenna **2290** can be fixed in position with a securing mechanism **2295** (e.g., a clamp and bolt). In one embodiment, this can allow the utilization of a secondary internal electronic auto-alignment (e.g., electromechanical or phased array) device to obtain and maintain fine alignment and robust connectivity to other remote antennas. This example can provide physical support for positioning devices to establish a relay daisy chain of connections that can support and relay aggregated backhaul traffic to and from a network fiber.

In one or more embodiments, system **2200** can accept and support (e.g., via inter-bracket plate **2280**) one or more electronic modules **2285** or enclosures (as shown in FIG. **23**) that include components which support communications including point-to-point mm-wave or sub-mm-wave radio and/or FSOC devices. In one embodiment, each electronics module **2285** can include port connectivity to at least two point-to-point radio modules, connection to other associated enclosures for sectorized radio distribution, and/or FSOC and optical fiber (network connection) and power.

In one or more embodiments, the electronics module **2285** can also support a 5G, or higher capacity, wireless access radio system to provide high capacity localized mobility access. The 5G electronics of the module **2285** can be connected to and supported by the point-to-point mm wave radios backhaul electronics, such as an add/drop interface.

The mounting bracket **2210** is illustrated in top, plan and side views of FIGS. **24A-24C**, respectively. The mounting bracket **2210** can include various holes for receiving securing mechanisms (screws, bolts and so forth) for securing the mounting bracket to the utility pole **2230** (e.g., screws **2214** shown in FIGS. **26A**, **29**), as well as securing other components to the mounting bracket, such as the inter-bracket plate **2280**, a lug **2225** (e.g., as shown in FIGS. **25A**, **B**), adjustable strap **2235** (e.g., via slots **2212** shown in FIGS. **24C**, **25A**, **26A**), and so forth.

In one or more embodiments, the mounting bracket **2210** can include sacrificial dimples **2216** (shown in FIG. **24A**) to facilitate connection with the utility pole **2230**. The dimples **2216** can be of various shapes, such as conical, to facilitate the connection and are located on an inner face of the mounting bracket **2210**. The dimples **2216** are adapted (such

as based on size, shape and/or material) to penetrate wood substrates and/or to crush and deform, in pressured contact, to a rigid metallic or concrete pole's surface texture. This intimate surface contact utilizing the dimples **2216** can provide a forced mechanical contact and resistance to the brackets slippage during temperature cycling.

In one or more embodiments, the mounting bracket **2210** can include deformable contact pads **2218**, such as rubber pads. For example, the deformable rubber pads **2218** can be co-located along with the sacrificial dimples **2216** and contact-glued to the inner surface of the mounting bracket **2210**. In one embodiment, the pads **2218** can have clear through-holes centered around the sacrificial dimples **2216**, and the pads can be approximately 2-3 times the thickness of the dimples, although selection of size and shape can depend on various factors including the materials being utilized. The pads **2218** are adapted (such as based on size, shape and/or material) to deform and comply to the surface of the utility pole **2230** as the mounting bracket **2210** is initially clamped to the utility pole via the clamping strap **2235** (e.g., which can be a metal strap such as an adjustable metal strap as shown in FIG. 26A). In one or more embodiments, when the mounting brackets **2210** are partially clamped, the compression of the pads **2218** can support the vertical placement of the mounting brackets on the utility pole **2230**, while allowing some limited bracket-to-pole spacing adjustments until the final bracket spacing is determined for the individual pole deployment. For example, the compressibility of the pads **2218** can allow the mounting bracket **2210** to be incrementally clamped onto the utility pole **2230** until the sacrificial dimples **2216** are brought into full engagement with the pole substrate.

An example of components that can be used with system **2200** can include a clamping bracket **2220** as shown in FIGS. 26A, 26B. The clamping bracket **2220** can be a C-shaped bracket that hinges freely around a lug **2225** (e.g., a threaded lug shown in FIGS. 25A, 25B, 26A) and that holds the cylindrical member **2240** (e.g., a rolled-pipe section) in a flattened hole that is adapted (such as based on size, shape and/or material) to allow the cylindrical member to slide and adjust in place until such time as the clamping bracket **2220** is compressed by a nut **2227** (e.g., as shown in FIGS. 26A, 26B) torqued down on the threaded lug **2225**. As shown in FIGS. 23 and 29, two of the clamping brackets **2220** can be slid onto the cylindrical member **2240**. The installer can then position this sub-assembly (i.e., the two clamping brackets **2220** on the cylindrical member **2240**) over two available threaded lugs **2225** as shown in FIGS. 26A and 29, which allows this sub-assembly to slide down the lugs until the sub-assembly bottoms out on the mounting bracket **2210**. In one embodiment, the cylindrical member **2240** can automatically find a common settled position between the two clamping brackets **2220** that is related to the spacing of the clamps around the pole. This embodiment can allow for a non-critical spacing of the mounting brackets **2210** around the utility pole **2230**, which saves time and reduces complexity in the installation procedures. For example, if two or more mounting brackets **2210** are attached to the pole at different heights, the clamping brackets **2220** can accommodate the differences.

In one embodiment, a group of sub-assemblies of the clamping brackets **2220** and the cylindrical member **2240** can be reproduced around the utility pole **2230** such as shown in FIG. 29. By overlapping the clamping brackets **2220** on particular threaded lugs **2225**, a fully enclosed ring of cylindrical members **2240** can be assembled to circumscribe the utility pole **2230** (e.g., in partially stacked con-

figurations). The threaded lugs **2225** can be long enough to accept the stacking of two or more clamping brackets **2220**, as illustrated by arrows **2901**. When the sub-assembly is positioned with respect to the threaded lugs **2225**, the locking nut **2227** can be assembled onto each threaded lug to clamp down the sub-assembly and rigidly secure the cylindrical members **2240** in place. In one embodiment, spacers **2228** can be used to facilitate the locking nut **2227** clamping down on the sub-assembly, as shown in FIG. 26B, 29. In another embodiment, the entire assembly of brackets, clamps lugs cylindrical members and carriages could be assembled and lightly tightened except for the assembly of one last cylindrical member onto its threaded lugs. This almost complete assembly could then be easily wrapped around and secured to the pole with the metal strap as shown in FIG. 29. The assembly could be then completed with the assembly of the final cylindrical member and associated carriages—allowing a very rapid assembly of the mounting elements prior to the addition of the radio modules and electronics enclosures.

As shown in FIG. 30, the threaded lug **2225** is adapted (e.g., based on a pivotal connection **3027** via a pin **2226** with the mounting bracket **2210**) to tilt and adjust to a vertical position in the case of a tapered utility pole **3030**. The pivoting of the threaded lug **2225** allows a horizontal assembly of network equipment, such as radio modules and enclosures, independent of the pole's taper.

The sub-assembly described above can be utilized for supporting mounting carriage **2260** and enabling selective movement (e.g., of an antenna **2290**) as to elevation and/or azimuth. In one or more embodiments prior to attaching the clamping brackets **2220** to the cylindrical member **2240**, one or more mounting carriages **2260** can be slid onto the cylindrical member (e.g., roughly centered along the cylindrical member), as is shown in FIG. 29. The clamping brackets **2220** can then be assembled on the cylindrical member **2240** and the sub-assembly (including the mounting carriage **2260**) can then be mounted on the threaded lugs **2225**. The mounting carriage **2260** is adapted (such as based on size, shape and/or material) to provide a desired location for attaching the antenna **2290**, such as a mm-wave, sub-mm-wave, and/or FSOC antenna module. The installed mounting carriage **2260** can provide an adjustable range of motion, such as in both elevation and azimuth.

The mounting carriage **2260** can include a core bearing **2262**, as shown in FIG. 28A. The core bearing **2262** can be adapted (such as based on size, shape and/or material) to slide onto the cylindrical member **2240** and provide side-to-side or lateral motion along the cylindrical member. In addition, an outer housing **2264** of the mounting carriage **2260** can be adapted (such as based on size, shape and/or material) to rotate about the cylindrical outer diameter of the core bearing **2262**, providing motion in elevation as illustrated in FIG. 28B.

FIG. 27A illustrates the mounting carriage **2260** positioned on the cylindrical member **2240** with cross-sectional views taken along A-A, B-B, C-C in FIGS. 27B, 27C, 27D, respectively. In one or more embodiments, both the core bearing **2262** and the outer housing **2264** are split; that is, a slot is cut out of the material allowing a clamping action of both the core bearing and the outer housing to clamp around and prevent movement based on a locking technique, such as tightening screws. The core bearing **2262** can have a particular shape for its inner bore or core bearing hole **2263** such that it is curved and designed to match the curve (or radius) of the cylindrical member **2240**. As an example, the sagittal offset of this curve from an otherwise straight bore

hole can prevent the core bearing **2262** from rotating while retaining the ability to slide from side to side along the cylindrical member **2240**. This curved feature provides a stable non-rotating reference surface. The outer housing **2264** can have a bore diameter to match the outer diameter of the core bearing **2262** and thus can be free to rotate on the core bearing's outer surface. In one embodiment, controlled motion in elevation can be achieved by using a fine-adjustment elevation screw **2266**, as illustrated in FIG. 27D. The elevation position can be secured by applying suitable clamping torque on the securing member(s) **2268** (e.g., clamping screw(s)) that locks both the outer housing **2264** and core bearing **2262** onto the cylindrical member **2240**. Additionally, the core bearing **2262** can allow for side-to-side motion, providing adjustment of a transmission field of view for the antenna **2290**. In one or more embodiments, this adaptation can enable or otherwise facilitate avoiding transmission path obstruction by, for example, the utility pole **2230** itself. In one or more embodiments, a grub nut **2269** can be provided for securing the core bearing **2262** while manual elevation alignment is being performed.

In one embodiment, the outer housing **2264** provides a perpendicular (to the core bearing hole **2263**) clampable hole or opening **2267** that is adapted (such as based on size, shape and/or material) to receive a rotatable antenna mount **2292**, which is connected with the antenna **2290**. When the antenna mount **2292** (and antenna **2290**) is assembled to the mounting carriage **2260** (via the opening **2267**) and the securing mechanism **2295** is in an unlocked state (e.g., the screw is loosened), the antenna can be rotated (e.g., 180 degrees or more or less), thus allowing manual azimuth link alignment adjustment, such as through use of a sighting tube **3125** shown in FIG. 31. The sighting tube **3125** can include a mirror **3150** to facilitate sighting a target using a human eye **3101**, such as a sighting target **3175** on another antenna.

In one or more embodiments depending on the diameter of the utility pole **2230**, one or more mounting carriages **2260** can be assembled onto a single cylindrical member **2240** and then assembled to the mounting brackets **2210**. This can provide a flexible assembly system allowing one or a cluster of antennas **2290** to be mounted with their electronic enclosures **2285** on a utility pole **2230**, providing the freedom and flexibility to build high capacity mm-wave backhaul and wireless access networks (or other types of networks) along streets and public spaces. The mounting bracket and/or other components utilized with the system **2200** can be made from various materials, including non-conducting materials.

In one or more embodiments, the carriage bearing is made up of two independent parts **2262** and **2264**. The part **2262** is cylindrical in its outer form, but its inner bore **2263** is not straight but is curved to match the arc of the cylindrical member **2240** that it is mounted to. When this part **2262** is not clamped down it is free to slide along the cylindrical member in an arced fashion controlled by the cylindrical member's radius of curvature. The curvature of the inner bore **2263** also has another property, as the bore is not straight but curved, it cannot rotate around its center axis like symmetric systems do. This inability to rotate around its axis, but be able to slide along the cylindrical member **2240** provides a stable configuration for an azimuth position adjustment but not an elevation adjustment. The outer cylindrical diameter of part **2262** is designed to couple with part **2264** and is a straight cylindrical bore so can provide the elevation adjustment as required for link alignment as shown in FIG. 28B. When clamped down, the inner bearing **2262** locks onto the cylindrical member **2240** and so cannot slide,

and part **2264** can be clamped onto the outer cylindrical diameter of part **2262** and so cannot rotate—thus locking the mounting carriage **2260** in place.

Referring to FIGS. 32-33, system **2200'** is shown with a pair of mounting brackets **2210** that are secured to a cross member **3231** of a utility pole **3230**. The mounting brackets can have various shapes, sizes and/or be made from various materials. In one embodiment, the mounting brackets **2210** are adapted to be attached to both a circular utility pole **3320**, and to a cross member **3231**. In this example, system **2200'** provides a stable platform for supporting the antenna **2290** and the electronics module **2285** via mounting brackets attached at a distal end **3292** of a cross member, while system **2200** provides a second stable platform for supporting another antenna **2290** and electronics module **2285** via mounting brackets **2210** attached to the utility pole **3230**. In this example, two support systems **2200** and **2200'** are utilized which can increase the number of network devices that can be positioned and utilized at a desired location (e.g., on a single utility pole).

In one or more embodiments, the mounting brackets **2210** can include openings or indentations that fit to the corners of the cross member **3231**. The openings in the mounting brackets **2210** can include dimples **3315** or screws or other extending members that can penetrate or engage the cross member **3231** in the area of the corner. In one embodiment the mounting brackets **2210** can include holes for fastening the mounting brackets **2210** to the cross member **3231** via screws or bolts. The mounting brackets **2210** can include deformable pads **3325**, which can be adapted to deform and comply with the surface of the cross member **3231**.

In one or more embodiments, the cylindrical member **2240**, or "radiused bar" can include an arc curvature with a radius that is compatible with its alternative use as providing a support surrounding the utility pole **3230**. For example, the cylindrical member **2240** can have a radius that is larger than that of the utility pole **3230** so that the same cylindrical member **2240**, or pre-shaped material, can be alternatively used at the utility pole **3230** or the distal end **3292** of the cross member **3231**. The support system, including the mounting brackets **2210**, the lugs, and the mounting carriage can allow the antenna and/or the electronics module **2285** to be suspended from the distal end of the **3292** of the cross member **3231** in an available and convenient to service location.

Referring to FIG. 34, system **2200"** is illustrated in which an antenna boom **3450** is utilized to support the antenna **2290**. The antenna boom **3450** can be adapted (such as based on size and/or shape) to allow the antenna **2290** to be positioned farther away from the utility pole **2230**. The boom **3450** can include boom mounts **3492** that mate with the opening **2267** in the outer housing **2264** of the mounting carriage **2260** (similar to the mating of the antenna mount **2292** with the opening **2267** as shown in FIG. 27B).

In one or more embodiments, the boom **3450** can include an end with a diameter so that it can slide into the bore of the outer housing **2264** (in place of the core bearing **2262**) of another mounting carriage **2160**. In one embodiment, the boom **3450** and/or the mounting bracket(s) **2210** can provide a mounting location for the electronics module (not shown). In one embodiment, the boom **3450** provides an adjustable side-offset from the utility pole **2230** (e.g., up to 24 inches or more), allowing one or more antennas **2290** to be positioned away from the utility pole, and for example, placing these antennas on the street side of the utility pole, which can often be a location with a favorable clear and unobstructed line-of-sight to nearby utility poles and other antennas in the

network. The boom antenna offset arrangement provided by the antenna boom **3450** can allow the clear space near or above the road to become a street level radio conduit—behaving almost as a waveguide. In one or more embodiments where system **2200** is being utilized, it can result in the local street configuration determining or otherwise being a factor in determining the network node deployment.

Referring to FIG. **35**, system **2200** is shown where multiple cylindrical members **2240** are arranged so as to fully circumscribe the utility pole **2230**. In this example, the antennas **2290** can be pointed in various directions (as indicated by arrows **3550**) to provide for a more complete field of transmitting and receiving wireless signals.

Turning now to FIG. **36**, a flow diagram of an example, non-limiting embodiment of a method **3600**, is shown. In particular, the method **3600** is presented for use with one or more functions and features presented in conjunction with FIGS. **1-35** for providing a support structure for network devices (e.g., wireless communication devices). At **3615**, a plurality of mounting brackets can be connected with a utility pole. As an example, an adjustable strap can be utilized to facilitate holding the mounting brackets in place as the mounting brackets are being secured to the utility pole, such as through screws or the like. Other structures, such as dimples and/or deformable pads can also be utilized to assist in holding the mounting brackets at a desired position with respect to the utility pole while also allowing for position adjustments during installation. At **3625**, a sub-assembly can be assembled which includes clamping brackets, a cylindrical member and a mounting carriage (on the cylindrical member). In one or more embodiments, the mounting carriage when in an unlocked state can slide along the cylindrical member and can rotate about the cylindrical member, and the mounting carriage when in a locked state cannot slide along the cylindrical member and cannot rotate about the cylindrical member.

At **3635**, the sub-assembly can be connected with the mounting brackets, such as by connecting the cylindrical member to first and second adjacent mounting brackets utilizing the clamping brackets of the sub-assembly. At **3645**, an antenna can be connected to the mounting carriage, such via an antenna mount. At **3655**, the antenna can be manually re-orientated, such as in elevation and azimuth, and then locked into position. In one or more embodiments, the antenna includes a dielectric antenna, and wireless signals can be transmitted based on electromagnetic waves that propagate without utilizing an electrical return path, where the electromagnetic waves are guided by a dielectric core of a cable coupled to a feed point of the dielectric antenna.

In one or more embodiments, the connecting of the antenna to the mounting carriage can include positioning an antenna boom mount of an antenna boom in an opening of the mounting carriage. An antenna mount of the antenna can then be inserted into an opening of another mounting carriage connected with the antenna boom, where the antenna mount when in an unlocked state rotates about the opening in the other antenna boom, and where the antenna mount when in a locked state does not rotate about the opening in the other mounting carriage.

In one or more embodiments, the connecting of the cylindrical member to the first and second mounting brackets includes connecting the cylindrical member to first and second lugs of the first and second mounting brackets, respectively, where the first and second lugs are pivotally connected to the first and second mounting brackets, respectively. In one or more embodiments, the method **3600** can

include adjusting a first securing member of the mounting carriage to adjust between the unlocked state and the locked state of the mounting carriage; and adjusting a second securing member of the mounting carriage to adjust between an unlocked state and a locked state of an antenna mount that is utilized in the connecting of the antenna to the mounting carriage. In one or more embodiments, the method **3600** can include connecting an inter-bracket plate with the first and second mounting brackets; and connecting an electronics module to the inter-bracket plate, where the electronics module enables wireless communications via the antenna. In one or more embodiments, the re-orientation of the antenna can be based on a sighting tube of the antenna.

Referring to FIG. **37**, a schematic diagram is shown for a network device **3700** that can be utilized in one or more of the embodiments described herein. In one or more embodiments, the network device **3700** allows for a connection with the transmission medium **3730**, allows for obtaining power (e.g., via an inductive coupling with the transmission medium), and/or allows for providing communications, including wireless communications. In one or more embodiments, one or more components of network device **3700** can be utilized with system **2200**. The network device **3700** being shown can include components that facilitate inductive coupling with the transmission medium **3730** to obtain power for the communication device and wireless communications.

In this example, the communication device **3700** can include an inductive power module **3705**, a waveguide(s) **3710** and a wireless device **3715**. The inductive power module **3705** and the waveguide **3710** can be integrated or otherwise physically connected to each other. The inductive power module **3705**, the waveguide **3710** and the wireless device **3715** can be coupled by way of a cable **3720** for providing communications and/or power. Inductive power module **3705** can include various features to facilitate obtaining, regulating and/or controlling power (via an inductive coupling with the transmission medium **3730**), such as housing portions, core portions, a secondary winding, a moveable or pivotal connection, a compressible material, a chargeable battery, a voltage rectifier and/or spike suppression circuit, a circuit board and so forth. In one or more embodiments, the inductive power module **3705** can include an inline EMP based high voltage/moderate current spike suppressor configured to respond to natural (e.g., solar CME) and/or man-made EMP events. The addition of this capability within or as an exterior module addition, can suppress EMP spikes on the MV or low voltage lines that would otherwise take out a large amount of the medium to low voltage connected infrastructure, vulnerable homes and small businesses. Waveguide **3710** (two of which are shown but in one or more embodiments a single surface waveguide can also be utilized) can include various features to facilitate communications by electromagnetic waves guided by the transmission medium **3730**, such as a transceiver, radiating element(s), a dielectric coupler, various circuit components (e.g., MMICs), and so forth. Wireless device **3715** can include various features to facilitate wireless communications, such as a transceiver, a feed point, a dielectric antenna, various circuit components, and so forth. Cable **3720** can include various features to facilitate providing communications and/or power between the inductive power module **3705**, the surface waveguide **3710** and the wireless device **3715**, such as a dielectric core, cladding, outer jacket, and so forth. In one embodiment, housing element **3715** multiple phased array poly modules can be housed in the housing rather than dielectric cones. An electrically active phased

array polyrod module can facilitate enhanced capabilities of beam steering and tracking, which are not easily achieved with dielectric cones. In addition, the beam steering function can provide 360 degree coverage while requiring fewer phased array polyrod modules than would be required using the passive dielectric cones.

In one or more embodiments, the inductive power module **3705** and the waveguide(s) **3710** can be physically connected to the transmission medium **3730**, such as through use of a separable core. In one or more embodiments, the wireless device **3715** can be coupled to a support structure **3750**, such as a pole that supports the transmission medium **3730**. In one or more embodiments, communications can be provided by the communication device **3700** by way of the waveguide(s) **3710** and/or by way of the wireless device **3715**. As an example, the surface waveguide **3710** can provide or receive electromagnetic waves at a physical interface of the transmission medium **3730** that propagate without utilizing an electrical return path, where the electromagnetic waves are guided by the transmission medium. Continuing with this example, a wireless signal can be radiated from a dielectric antenna of the wireless device **3715** in response to electromagnetic waves being received at a feed point of the dielectric antenna via a dielectric core of the cable **3720**. In one or more embodiments, the wireless device **3715** can receive wireless signals that are used in generating electromagnetic waves provided to the dielectric core of the cable **3720**. In one or more embodiments, communication device **3700** allows for selective use of different techniques of communication (wireless or guided by the transmission medium **3730**).

Turning now to FIGS. **38A** and **38B**, block diagrams illustrating example, non-limiting embodiments of a dielectric antenna and corresponding gain and field intensity plots in accordance with various aspects described herein are shown. FIG. **38A** depicts a dielectric horn antenna **3891** having a conical structure which can be used with the network device **3700**. The dielectric horn antenna **3891** is coupled to a feed point **3892**, which can also be comprised of a dielectric material. In one embodiment, for example, the dielectric horn antenna **3891** and the feed point **3892** can be constructed of dielectric materials such as a polyethylene material, a polyurethane material or other suitable dielectric material (e.g., a synthetic resin, other plastics, etc.). In an embodiment, the dielectric horn antenna **3891** and the feed point **3892** can be adapted to be substantially or entirely devoid of any conductive materials. For example, the external surfaces **3897** of the dielectric horn antenna **3891** and the feed point **3892** can be non-conductive substantially non-conductive with at least 95% of the external surface area being non-conductive and the dielectric materials used to construct the dielectric horn antenna **3891** and the feed point **3892** can be such that they substantially do not contain impurities that may be conductive (e.g., such as less than 1 part per thousand) or result in imparting conductive properties. In other embodiments however, a limited number of conductive components can be used such as a metallic connector component used at the feed point **3892**, one or more screw, rivets or other coupling elements used to bind components to one another, and/or one or more structural elements that do not significantly alter the radiation pattern of the dielectric antenna.

The feed point **3892** can be adapted to couple to a core **3852**. In one embodiment, the feed point **3892** can be coupled to the core **3852** utilizing a joint (not shown in FIG. **38A**) such as a splicing device. Other embodiments for coupling the feed point **3892** to the core **3852** can be used.

In an embodiment, the joint can be configured to cause the feed point **3892** to touch an endpoint of the core **3852**. In another embodiment, the joint can create a gap between the feed point **3892** and the endpoint of the core **3852**. In yet another embodiment, the joint can cause the feed point **3892** and the core **3852** to be coaxially aligned or partially misaligned. Notwithstanding any combination of the foregoing embodiments, electromagnetic waves can in whole or at least in part propagate between the junction of the feed point **3892** and the core **3852**.

The cable **3850** can be coupled to a waveguide system configured to select a wave mode (e.g., non-fundamental wave mode, fundamental wave mode, a hybrid wave mode, or combinations thereof as described earlier) and transmit instances of electromagnetic waves having a non-optical operating frequency (e.g., 60 GHz). The electromagnetic waves can be directed to an interface of the cable **3850**.

The instances of electromagnetic waves generated by the waveguide system can induce a combined electromagnetic wave having the selected wave mode that propagates from the core **3852** to the feed point **3892**. The combined electromagnetic wave can propagate partly inside the core **3852** and partly on an outer surface of the core **3852**. Once the combined electromagnetic wave has propagated through the junction between the core **3852** and the feed point **3892**, the combined electromagnetic wave can continue to propagate partly inside the feed point **3892** and partly on an outer surface of the feed point **3892**. In some embodiments, the portion of the combined electromagnetic wave that propagates on the outer surface of the core **3852** and the feed point **3892** is small. In these embodiments, the combined electromagnetic wave can be said to be guided by and tightly coupled to the core **3852** and the feed point **3892** while propagating longitudinally towards the dielectric antenna **3891**.

When the combined electromagnetic wave reaches a proximal portion of the dielectric antenna **3891** (at a junction **3892'** between the feed point **3892** and the dielectric antenna **3891**), the combined electromagnetic wave enters the proximal portion of the dielectric antenna **3891** and propagates longitudinally along an axis of the dielectric antenna **3891** (shown as a hashed line). By the time the combined electromagnetic wave reaches the aperture **3893**, the combined electromagnetic wave has an intensity pattern similar to the one shown in FIG. **38B**. The electric field intensity pattern of FIG. **38B** shows that the electric fields of the combined electromagnetic waves are strongest in a center region of the aperture **3893** and weaker in the outer regions. In an embodiment, where the wave mode of the electromagnetic waves propagating in the dielectric antenna **3891** is a hybrid wave mode (e.g., HE<sub>11</sub>), the leakage of the electromagnetic waves at the external surfaces **3897** is reduced or in some instances eliminated.

In an embodiment, the far field antenna gain pattern depicted in FIG. **38B** can be widened by decreasing the operating frequency of the combined electromagnetic wave. Similarly, the gain pattern can be narrowed by increasing the operating frequency of the combined electromagnetic wave. Accordingly, a width of a beam of wireless signals emitted by the aperture **3893** can be controlled by configuring the waveguide system to increase or decrease the operating frequency of the combined electromagnetic wave.

The dielectric antenna **3891** of FIG. **38A** can also be used for receiving wireless signals. Wireless signals received by the dielectric antenna **3891** at the aperture **3893** induce electromagnetic waves in the dielectric antenna **3891** that propagate towards the feed point **3892**. The electromagnetic

waves continue to propagate from the feed point **3892** to the core **3852**. In this configuration, the waveguide system can perform bidirectional communications utilizing the dielectric antenna **3891**. It is further noted that in some embodiments the core **3852** of the cable **3850** (shown with dashed lines) can be configured to be collinear with the feed point **3892** to avoid a bend shown in FIG. **38A**. In some embodiments, a collinear configuration can reduce an alteration of the electromagnetic due to the bend in cable **3850**.

In one or more embodiments, the cable can include a dielectric core covered by a shell, and the wireless signal radiates from an aperture of the dielectric antenna. In one or more embodiments, the dielectric antenna has substantially or entirely no conductive external surfaces, and the dielectric antenna has a composition that is substantially or entirely devoid of conductive materials. In one or more embodiments, the dielectric core is opaque, thereby resistant to propagation of electromagnetic waves having an optical operating frequency. In one or more embodiments, the shell comprises a dielectric layer disposed on the dielectric core. In one or more embodiments, the dielectric core comprises a first dielectric constant, where the shell comprises a second dielectric constant, and where the first dielectric constant exceeds the second dielectric constant to enable the electromagnetic waves to be bound to the dielectric core. In one or more embodiments, the dielectric antenna comprises a high density dielectric material. In one or more embodiments, the high density dielectric material comprises a high density polyethylene material, a high density polyurethane material, or a synthetic resin.

In one or more embodiments, the cross-sections of the dielectric feed point and the dielectric core have similar dimensions. In one or more embodiments, the shell comprises a low density dielectric material. In one or more embodiments, the low density dielectric material comprises an expanded polyethylene material. In one or more embodiments, the transmitter comprises a slotted waveguide for inducing the electromagnetic waves guided by the dielectric core. In one or more embodiments, the transmitter comprises a microwave circuit coupled to an antenna and a waveguide structure for inducing the electromagnetic waves guided by the dielectric core. In one or more embodiments, the transmitter is configured to perform waveform adjustments to the wireless signal radiated by the dielectric antenna. In one or more embodiments, the electromagnetic waves have a hybrid wave mode. In one or more embodiments, the dielectric antenna has a horn structure. In one or more embodiments, the dielectric antenna has a pyramidal structure.

Turning now to FIG. **39A**, a block diagram illustrating an example, non-limiting embodiment of a transmission medium **3900** for propagating guided electromagnetic waves is shown. Transmission medium **3900** can be utilized as cable **3720** in network device **3700**. In particular, a further example of transmission medium **125** presented in conjunction with FIG. **1** is presented. In an embodiment, the transmission medium **3900** can comprise a first dielectric material **3902** and a second dielectric material **3904** disposed thereon. In an embodiment, the first dielectric material **3902** can comprise a dielectric core (referred to herein as dielectric core **3902**) and the second dielectric material **3904** can comprise a cladding or shell such as a dielectric foam that surrounds in whole or in part the dielectric core (referred to herein as dielectric foam **3904**). In an embodiment, the dielectric core **3902** and dielectric foam **3904** can be coaxially aligned to each other (although not necessary). In an embodiment, the combination of the dielectric core **3902**

and the dielectric foam **3904** can be flexed or bent at least by 45 degrees without damaging the materials of the dielectric core **3902** and the dielectric foam **3904**. In an embodiment, an outer surface of the dielectric foam **3904** can be further surrounded in whole or in part by a third dielectric material **3906**, which can serve as an outer jacket (referred to herein as jacket **3906**). The jacket **3906** can prevent exposure of the dielectric core **3902** and the dielectric foam **3904** to an environment that can adversely affect the propagation of electromagnetic waves (e.g., water, soil, etc.).

The dielectric core **3902** can comprise, for example, a high density polyethylene material, a high density polyurethane material, or other suitable dielectric material(s). The dielectric foam **3904** can comprise, for example, a cellular plastic material such an expanded polyethylene material, or other suitable dielectric material(s). The jacket **3906** can comprise, for example, a polyethylene material or equivalent. In an embodiment, the dielectric constant of the dielectric foam **3904** can be (or substantially) lower than the dielectric constant of the dielectric core **3902**. For example, the dielectric constant of the dielectric core **3902** can be approximately 2.3 while the dielectric constant of the dielectric foam **3904** can be approximately 1.15 (slightly higher than the dielectric constant of air).

The dielectric core **3902** can be used for receiving signals in the form of electromagnetic waves from a launcher or other coupling device described herein which can be configured to launch guided electromagnetic waves on the transmission medium **3900**. In one embodiment, the transmission **3900** can be coupled to a hollow waveguide **3008** structured as, for example, a circular waveguide **3909**, which can receive electromagnetic waves from a radiating device such as a stub antenna (not shown). The hollow waveguide **3908** can in turn induce guided electromagnetic waves in the dielectric core **3902**. In this configuration, the guided electromagnetic waves are guided by or bound to the dielectric core **3902** and propagate longitudinally along the dielectric core **3902**. By adjusting electronics of the launcher, an operating frequency of the electromagnetic waves can be chosen such that a field intensity profile **3910** of the guided electromagnetic waves extends nominally (or not at all) outside of the jacket **3906**.

By maintaining most (if not all) of the field strength of the guided electromagnetic waves within portions of the dielectric core **3902**, the dielectric foam **3904** and/or the jacket **3906**, the transmission medium **3900** can be used in hostile environments without adversely affecting the propagation of the electromagnetic waves propagating therein. For example, the transmission medium **3900** can be buried in soil with no (or nearly no) adverse effect to the guided electromagnetic waves propagating in the transmission medium **3900**. Similarly, the transmission medium **3900** can be exposed to water (e.g., rain or placed underwater) with no (or nearly no) adverse effect to the guided electromagnetic waves propagating in the transmission medium **3900**. In an embodiment, the propagation loss of guided electromagnetic waves in the foregoing embodiments can be 1 to 2 dB per meter or better at an operating frequency of 60 GHz. Depending on the operating frequency of the guided electromagnetic waves and/or the materials used for the transmission medium **3900** other propagation losses may be possible. Additionally, depending on the materials used to construct the transmission medium **3900**, the transmission medium **3900** can in some embodiments be flexed laterally with no (or nearly no) adverse effect to the guided electromagnetic waves propagating through the dielectric core **3902** and the dielectric foam **3904**.

FIG. 39B depicts a transmission medium 3920 that differs from the transmission medium 3900 of FIG. 39A, yet provides a further example of the transmission medium 125 presented in conjunction with FIG. 1. The transmission medium 3920 shows similar reference numerals for similar elements of the transmission medium 3900 of FIG. 39A. In contrast to the transmission medium 3000, the transmission medium 3920 comprises a conductive core 3922 having an insulation layer 3923 surrounding the conductive core 3922 in whole or in part. The combination of the insulation layer 3923 and the conductive core 3922 will be referred to herein as an insulated conductor 3925. In the illustration of FIG. 39B, the insulation layer 3923 is covered in whole or in part by a dielectric foam 3904 and jacket 3906, which can be constructed from the materials previously described. In an embodiment, the insulation layer 3923 can comprise a dielectric material, such as polyethylene, having a higher dielectric constant than the dielectric foam 3904 (e.g., 2.3 and 1.15, respectively). In an embodiment, the components of the transmission medium 3920 can be coaxially aligned (although not necessary). In an embodiment, a hollow waveguide 3908 having metal plates 3909, which can be separated from the insulation layer 3923 (although not necessary) can be used to launch guided electromagnetic waves that substantially propagate on an outer surface of the insulation layer 3923, however other coupling devices as described herein can likewise be employed. In an embodiment, the guided electromagnetic waves can be sufficiently guided by or bound by the insulation layer 3923 to guide the electromagnetic waves longitudinally along the insulation layer 3923. By adjusting operational parameters of the launcher, an operating frequency of the guided electromagnetic waves launched by the hollow waveguide 3908 can generate an electric field intensity profile 3924 that results in the guided electromagnetic waves being substantially confined within the dielectric foam 3904 thereby preventing the guided electromagnetic waves from being exposed to an environment (e.g., water, soil, etc.) that adversely affects propagation of the guided electromagnetic waves via the transmission medium 3920.

FIG. 39C depicts a transmission medium 3930 that differs from the transmission mediums 3900 and 3920 of FIGS. 39A and 39B, yet provides a further example of the transmission medium 125 presented in conjunction with FIG. 1. The transmission medium 3930 shows similar reference numerals for similar elements of the transmission mediums 3900 and 3920 of FIGS. 39A and 39B, respectively. In contrast to the transmission mediums 3900 and 3920, the transmission medium 3930 comprises a bare (or uninsulated) conductor 3932 surrounded in whole or in part by the dielectric foam 3904 and the jacket 3906, which can be constructed from the materials previously described. In an embodiment, the components of the transmission medium 3930 can be coaxially aligned (although not necessary). In an embodiment, a hollow waveguide 3908 having metal plates 3909 coupled to the bare conductor 3932 can be used to launch guided electromagnetic waves that substantially propagate on an outer surface of the bare conductor 3932, however other coupling devices described herein can likewise be employed. In an embodiment, the guided electromagnetic waves can be sufficiently guided by or bound by the bare conductor 3932 to guide the guided electromagnetic waves longitudinally along the bare conductor 3932. By adjusting operational parameters of the launcher, an operating frequency of the guided electromagnetic waves launched by the hollow waveguide 3908 can generate an electric field intensity profile 3934 that results in the guided electromag-

netic waves being substantially confined within the dielectric foam 3904 thereby preventing the guided electromagnetic waves from being exposed to an environment (e.g., water, soil, etc.) that adversely affects propagation of the electromagnetic waves via the transmission medium 3930.

It should be noted that the hollow launcher 3908 used with the transmission mediums 3900, 3920 and 3930 of FIGS. 39A, 39B and 39C, respectively, can be replaced with other launchers or coupling devices. Additionally, the propagation mode(s) of the electromagnetic waves for any of the foregoing embodiments can be fundamental mode(s), a non-fundamental (or asymmetric) mode(s), or combinations thereof.

Referring now to FIG. 40, there is illustrated a block diagram of a computing environment in accordance with various aspects described herein. In order to provide additional context for various embodiments of the embodiments described herein, FIG. 40 and the following discussion are intended to provide a brief, general description of a suitable computing environment 4000 in which the various embodiments of the subject disclosure can be implemented. While the embodiments have been described above in the general context of computer-executable instructions that can run on one or more computers, those skilled in the art will recognize that the embodiments can be also implemented in combination with other program modules and/or as a combination of hardware and software.

Generally, program modules comprise routines, programs, components, data structures, etc., that perform particular tasks or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the inventive methods can be practiced with other computer system configurations, comprising single-processor or multiprocessor computer systems, minicomputers, mainframe computers, as well as personal computers, hand-held computing devices, microprocessor-based or programmable consumer electronics, and the like, each of which can be operatively coupled to one or more associated devices.

As used herein, a processing circuit includes processor as well as other application specific circuits such as an application specific integrated circuit, digital logic circuit, state machine, programmable gate array or other circuit that processes input signals or data and that produces output signals or data in response thereto. It should be noted that while any functions and features described herein in association with the operation of a processor could likewise be performed by a processing circuit.

The terms "first," "second," "third," and so forth, as used in the claims, unless otherwise clear by context, is for clarity only and doesn't otherwise indicate or imply any order in time. For instance, "a first determination," "a second determination," and "a third determination," does not indicate or imply that the first determination is to be made before the second determination, or vice versa, etc.

The illustrated embodiments of the embodiments herein can be also practiced in distributed computing environments where certain tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules can be located in both local and remote memory storage devices.

Computing devices typically comprise a variety of media, which can comprise computer-readable storage media and/or communications media, which two terms are used herein differently from one another as follows. Computer-readable storage media can be any available storage media that can be accessed by the computer and comprises both volatile and

nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer-readable storage media can be implemented in connection with any method or technology for storage of information such as computer-readable instructions, program modules, structured data or unstructured data.

Computer-readable storage media can comprise, but are not limited to, random access memory (RAM), read only memory (ROM), electrically erasable programmable read only memory (EEPROM), flash memory or other memory technology, compact disk read only memory (CD-ROM), digital versatile disk (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices or other tangible and/or non-transitory media which can be used to store desired information. In this regard, the terms “tangible” or “non-transitory” herein as applied to storage, memory or computer-readable media, are to be understood to exclude only propagating transitory signals per se as modifiers and do not relinquish rights to all standard storage, memory or computer-readable media that are not only propagating transitory signals per se.

Computer-readable storage media can be accessed by one or more local or remote computing devices, e.g., via access requests, queries or other data retrieval protocols, for a variety of operations with respect to the information stored by the medium.

Communications media typically embody computer-readable instructions, data structures, program modules or other structured or unstructured data in a data signal such as a modulated data signal, e.g., a carrier wave or other transport mechanism, and comprises any information delivery or transport media. The term “modulated data signal” or signals refers to a signal that has one or more of its characteristics set or changed in such a manner as to encode information in one or more signals. By way of example, and not limitation, communication media comprise wired media, such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media.

With reference again to FIG. 40, the example environment 4000 for transmitting and receiving signals via or forming at least part of a base station (e.g., base station devices 1504, macrocell site 1502, or base stations 1614) or central office (e.g., central office 1501 or 1611). At least a portion of the example environment 4000 can also be used for transmission devices 101 or 102. The example environment can comprise a computer 4002, the computer 4002 comprising a processing unit 4004, a system memory 4006 and a system bus 4008. The system bus 4008 couples system components including, but not limited to, the system memory 4006 to the processing unit 4004. The processing unit 4004 can be any of various commercially available processors. Dual microprocessors and other multiprocessor architectures can also be employed as the processing unit 4004.

The system bus 4008 can be any of several types of bus structure that can further interconnect to a memory bus (with or without a memory controller), a peripheral bus, and a local bus using any of a variety of commercially available bus architectures. The system memory 4006 comprises ROM 4010 and RAM 4012. A basic input/output system (BIOS) can be stored in a non-volatile memory such as ROM, erasable programmable read only memory (EPROM), EEPROM, which BIOS contains the basic routines that help to transfer information between elements

within the computer 4002, such as during startup. The RAM 4012 can also comprise a high-speed RAM such as static RAM for caching data.

The computer 4002 further comprises an internal hard disk drive (HDD) 4014 (e.g., EIDE, SATA), which internal hard disk drive 4014 can also be configured for external use in a suitable chassis (not shown), a magnetic floppy disk drive (FDD) 4016, (e.g., to read from or write to a removable diskette 4018) and an optical disk drive 4020, (e.g., reading a CD-ROM disk 4022 or, to read from or write to other high capacity optical media such as the DVD). The hard disk drive 4014, magnetic disk drive 4016 and optical disk drive 4020 can be connected to the system bus 4008 by a hard disk drive interface 4024, a magnetic disk drive interface 4026 and an optical drive interface 4028, respectively. The interface 4024 for external drive implementations comprises at least one or both of Universal Serial Bus (USB) and Institute of Electrical and Electronics Engineers (IEEE) 1394 interface technologies. Other external drive connection technologies are within contemplation of the embodiments described herein.

The drives and their associated computer-readable storage media provide nonvolatile storage of data, data structures, computer-executable instructions, and so forth. For the computer 4002, the drives and storage media accommodate the storage of any data in a suitable digital format. Although the description of computer-readable storage media above refers to a hard disk drive (HDD), a removable magnetic diskette, and a removable optical media such as a CD or DVD, it should be appreciated by those skilled in the art that other types of storage media which are readable by a computer, such as zip drives, magnetic cassettes, flash memory cards, cartridges, and the like, can also be used in the example operating environment, and further, that any such storage media can contain computer-executable instructions for performing the methods described herein.

A number of program modules can be stored in the drives and RAM 4012, comprising an operating system 4030, one or more application programs 4032, other program modules 4034 and program data 4036. All or portions of the operating system, applications, modules, and/or data can also be cached in the RAM 4012. The systems and methods described herein can be implemented utilizing various commercially available operating systems or combinations of operating systems. Examples of application programs 4032 that can be implemented and otherwise executed by processing unit 4004 include the diversity selection determining performed by transmission device 101 or 102.

A user can enter commands and information into the computer 4002 through one or more wired/wireless input devices, e.g., a keyboard 4038 and a pointing device, such as a mouse 4040. Other input devices (not shown) can comprise a microphone, an infrared (IR) remote control, a joystick, a game pad, a stylus pen, touch screen or the like. These and other input devices are often connected to the processing unit 4004 through an input device interface 4042 that can be coupled to the system bus 4008, but can be connected by other interfaces, such as a parallel port, an IEEE 1394 serial port, a game port, a universal serial bus (USB) port, an IR interface, etc.

A monitor 4044 or other type of display device can be also connected to the system bus 4008 via an interface, such as a video adapter 4046. It will also be appreciated that in alternative embodiments, a monitor 4044 can also be any display device (e.g., another computer having a display, a smart phone, a tablet computer, etc.) for receiving display information associated with computer 4002 via any com-

munication means, including via the Internet and cloud-based networks. In addition to the monitor **4044**, a computer typically comprises other peripheral output devices (not shown), such as speakers, printers, etc.

The computer **4002** can operate in a networked environment using logical connections via wired and/or wireless communications to one or more remote computers, such as a remote computer(s) **4048**. The remote computer(s) **4048** can be a workstation, a server computer, a router, a personal computer, portable computer, microprocessor-based entertainment appliance, a peer device or other common network node, and typically comprises many or all of the elements described relative to the computer **4002**, although, for purposes of brevity, only a memory/storage device **4050** is illustrated. The logical connections depicted comprise wired/wireless connectivity to a local area network (LAN) **4052** and/or larger networks, e.g., a wide area network (WAN) **4054**. Such LAN and WAN networking environments are commonplace in offices and companies, and facilitate enterprise-wide computer networks, such as intranets, all of which can connect to a global communications network, e.g., the Internet.

When used in a LAN networking environment, the computer **4002** can be connected to the local network **4052** through a wired and/or wireless communication network interface or adapter **4056**. The adapter **4056** can facilitate wired or wireless communication to the LAN **4052**, which can also comprise a wireless AP disposed thereon for communicating with the wireless adapter **4056**.

When used in a WAN networking environment, the computer **4002** can comprise a modem **4058** or can be connected to a communications server on the WAN **4054** or has other means for establishing communications over the WAN **4054**, such as by way of the Internet. The modem **4058**, which can be internal or external and a wired or wireless device, can be connected to the system bus **4008** via the input device interface **4042**. In a networked environment, program modules depicted relative to the computer **4002** or portions thereof, can be stored in the remote memory/storage device **4050**. It will be appreciated that the network connections shown are example and other means of establishing a communications link between the computers can be used.

The computer **4002** can be operable to communicate with any wireless devices or entities operatively disposed in wireless communication, e.g., a printer, scanner, desktop and/or portable computer, portable data assistant, communications satellite, any piece of equipment or location associated with a wirelessly detectable tag (e.g., a kiosk, news stand, restroom), and telephone. This can comprise Wireless Fidelity (Wi-Fi) and BLUETOOTH® wireless technologies. Thus, the communication can be a predefined structure as with a conventional network or simply an ad hoc communication between at least two devices.

Wi-Fi can allow connection to the Internet from a couch at home, a bed in a hotel room or a conference room at work, without wires. Wi-Fi is a wireless technology similar to that used in a cell phone that enables such devices, e.g., computers, to send and receive data indoors and out; anywhere within the range of a base station. Wi-Fi networks use radio technologies called IEEE 802.11 (a, b, g, n, ac, ag etc.) to provide secure, reliable, fast wireless connectivity. A Wi-Fi network can be used to connect computers to each other, to the Internet, and to wired networks (which can use IEEE 802.3 or Ethernet). Wi-Fi networks operate in the unlicensed 2.4 and 5 GHz radio bands for example or with products that contain both bands (dual band), so the networks can provide

real-world performance similar to the basic 10BaseT wired Ethernet networks used in many offices.

FIG. **41** presents an example embodiment **4100** of a mobile network platform **4110** that can implement and exploit one or more aspects of the disclosed subject matter described herein. In one or more embodiments, the mobile network platform **4110** can generate and receive signals transmitted and received by base stations (e.g., base station devices **1504**, macrocell site **1502**, or base stations **1614**), central office (e.g., central office **1501** or **1611**), or transmission device **101** or **102** associated with the disclosed subject matter. Generally, wireless network platform **4110** can comprise components, e.g., nodes, gateways, interfaces, servers, or disparate platforms, that facilitate both packet-switched (PS) (e.g., internet protocol (IP), frame relay, asynchronous transfer mode (ATM)) and circuit-switched (CS) traffic (e.g., voice and data), as well as control generation for networked wireless telecommunication. As a non-limiting example, wireless network platform **4110** can be included in telecommunications carrier networks, and can be considered carrier-side components as discussed elsewhere herein. Mobile network platform **4110** comprises CS gateway node(s) **4122** which can interface CS traffic received from legacy networks like telephony network(s) **4140** (e.g., public switched telephone network (PSTN), or public land mobile network (PLMN)) or a signaling system #7 (SS7) network **4170**. Circuit switched gateway node(s) **4122** can authorize and authenticate traffic (e.g., voice) arising from such networks. Additionally, CS gateway node(s) **4122** can access mobility, or roaming, data generated through SS7 network **4170**; for instance, mobility data stored in a visited location register (VLR), which can reside in memory **4130**. Moreover, CS gateway node(s) **4122** interfaces CS-based traffic and signaling and PS gateway node(s) **4118**. As an example, in a 3GPP UMTS network, CS gateway node(s) **4122** can be realized at least in part in gateway GPRS support node(s) (GGSN). It should be appreciated that functionality and specific operation of CS gateway node(s) **4122**, PS gateway node(s) **4118**, and serving node(s) **4116**, is provided and dictated by radio technology(ies) utilized by mobile network platform **4110** for telecommunication.

In addition to receiving and processing CS-switched traffic and signaling, PS gateway node(s) **4118** can authorize and authenticate PS-based data sessions with served mobile devices. Data sessions can comprise traffic, or content(s), exchanged with networks external to the wireless network platform **4110**, like wide area network(s) (WANs) **4150**, enterprise network(s) **4170**, and service network(s) **4180**, which can be embodied in local area network(s) (LANs), can also be interfaced with mobile network platform **4110** through PS gateway node(s) **4118**. It is to be noted that WANs **4150** and enterprise network(s) **4160** can embody, at least in part, a service network(s) like IP multimedia subsystem (IMS). Based on radio technology layer(s) available in technology resource(s) **4117**, packet-switched gateway node(s) **4118** can generate packet data protocol contexts when a data session is established; other data structures that facilitate routing of packetized data also can be generated. To that end, in an aspect, PS gateway node(s) **4118** can comprise a tunnel interface (e.g., tunnel termination gateway (TTG) in 3GPP UMTS network(s) (not shown)) which can facilitate packetized communication with disparate wireless network(s), such as Wi-Fi networks.

In embodiment **4100**, wireless network platform **4110** also comprises serving node(s) **4116** that, based upon available radio technology layer(s) within technology resource(s)

**4117**, convey the various packetized flows of data streams received through PS gateway node(s) **4118**. It is to be noted that for technology resource(s) **4117** that rely primarily on CS communication, server node(s) can deliver traffic without reliance on PS gateway node(s) **4118**; for example, server node(s) can embody at least in part a mobile switching center. As an example, in a 3GPP UMTS network, serving node(s) **4116** can be embodied in serving GPRS support node(s) (SGSN).

For radio technologies that exploit packetized communication, server(s) **4114** in wireless network platform **4110** can execute numerous applications that can generate multiple disparate packetized data streams or flows, and manage (e.g., schedule, queue, format . . . ) such flows. Such application(s) can comprise add-on features to standard services (for example, provisioning, billing, customer support . . . ) provided by wireless network platform **4110**. Data streams (e.g., content(s) that are part of a voice call or data session) can be conveyed to PS gateway node(s) **4118** for authorization/authentication and initiation of a data session, and to serving node(s) **4116** for communication thereafter. In addition to application server, server(s) **4114** can comprise utility server(s), a utility server can comprise a provisioning server, an operations and maintenance server, a security server that can implement at least in part a certificate authority and firewalls as well as other security mechanisms, and the like. In an aspect, security server(s) secure communication served through wireless network platform **4110** to ensure network's operation and data integrity in addition to authorization and authentication procedures that CS gateway node(s) **4122** and PS gateway node(s) **4118** can enact. Moreover, provisioning server(s) can provision services from external network(s) like networks operated by a disparate service provider; for instance, WAN **4150** or Global Positioning System (GPS) network(s) (not shown). Provisioning server(s) can also provision coverage through networks associated to wireless network platform **4110** (e.g., deployed and operated by the same service provider), such as the distributed antennas networks shown in FIG. 1(s) that enhance wireless service coverage by providing more network coverage. Repeater devices such as those shown in FIGS. 7, 8, and 9 also improve network coverage in order to enhance subscriber service experience by way of UE **4175**.

It is to be noted that server(s) **4114** can comprise one or more processors configured to confer at least in part the functionality of macro network platform **4110**. To that end, the one or more processor can execute code instructions stored in memory **4130**, for example. It is should be appreciated that server(s) **4114** can comprise a content manager **4115**, which operates in substantially the same manner as described hereinbefore.

In example embodiment **4100**, memory **4130** can store information related to operation of wireless network platform **4110**. Other operational information can comprise provisioning information of mobile devices served through wireless platform network **4110**, subscriber databases; application intelligence, pricing schemes, e.g., promotional rates, flat-rate programs, couponing campaigns; technical specification(s) consistent with telecommunication protocols for operation of disparate radio, or wireless, technology layers; and so forth. Memory **4130** can also store information from at least one of telephony network(s) **4140**, WAN **4150**, enterprise network(s) **4170**, or SS7 network **4160**. In an aspect, memory **4130** can be, for example, accessed as part of a data store component or as a remotely connected memory store.

In order to provide a context for the various aspects of the disclosed subject matter, FIG. 41, and the following discussion, are intended to provide a brief, general description of a suitable environment in which the various aspects of the disclosed subject matter can be implemented. While the subject matter has been described above in the general context of computer-executable instructions of a computer program that runs on a computer and/or computers, those skilled in the art will recognize that the disclosed subject matter also can be implemented in combination with other program modules. Generally, program modules comprise routines, programs, components, data structures, etc. that perform particular tasks and/or implement particular abstract data types.

FIG. 42 depicts an illustrative embodiment of a communication device **4200**. The communication device **4200** can serve as an illustrative embodiment of devices such as mobile devices and in-building devices referred to by the subject disclosure (e.g., in FIGS. 15, 16A and 16B).

The communication device **4200** can comprise a wireline and/or wireless transceiver **4202** (herein transceiver **4202**), a user interface (UI) **4204**, a power supply **4214**, a location receiver **4216**, a motion sensor **4218**, an orientation sensor **4220**, and a controller **4206** for managing operations thereof. The transceiver **4202** can support short-range or long-range wireless access technologies such as Bluetooth®, ZigBee®, WiFi, DECT, or cellular communication technologies, just to mention a few (Bluetooth® and ZigBee® are trademarks registered by the Bluetooth® Special Interest Group and the ZigBee® Alliance, respectively). Cellular technologies can include, for example, CDMA-1x, UMTS/HSDPA, GSM/GPRS, TDMA/EDGE, EV/DO, WiMAX, SDR, LTE, as well as other next generation wireless communication technologies as they arise. The transceiver **4202** can also be adapted to support circuit-switched wireline access technologies (such as PSTN), packet-switched wireline access technologies (such as TCP/IP, VoIP, etc.), and combinations thereof.

The UI **4204** can include a depressible or touch-sensitive keypad **4208** with a navigation mechanism such as a roller ball, a joystick, a mouse, or a navigation disk for manipulating operations of the communication device **4200**. The keypad **4208** can be an integral part of a housing assembly of the communication device **4200** or an independent device operably coupled thereto by a tethered wireline interface (such as a USB cable) or a wireless interface supporting for example Bluetooth®. The keypad **4208** can represent a numeric keypad commonly used by phones, and/or a QWERTY keypad with alphanumeric keys. The UI **4204** can further include a display **4210** such as monochrome or color LCD (Liquid Crystal Display), OLED (Organic Light Emitting Diode) or other suitable display technology for conveying images to an end user of the communication device **4200**. In an embodiment where the display **4210** is touch-sensitive, a portion or all of the keypad **4208** can be presented by way of the display **4210** with navigation features.

The display **4210** can use touch screen technology to also serve as a user interface for detecting user input. As a touch screen display, the communication device **4200** can be adapted to present a user interface having graphical user interface (GUI) elements that can be selected by a user with a touch of a finger. The touch screen display **4210** can be equipped with capacitive, resistive or other forms of sensing technology to detect how much surface area of a user's finger has been placed on a portion of the touch screen display. This sensing information can be used to control the

manipulation of the GUI elements or other functions of the user interface. The display **4210** can be an integral part of the housing assembly of the communication device **4200** or an independent device communicatively coupled thereto by a tethered wireline interface (such as a cable) or a wireless interface.

The UI **4204** can also include an audio system **4212** that utilizes audio technology for conveying low volume audio (such as audio heard in proximity of a human ear) and high volume audio (such as speakerphone for hands free operation). The audio system **4212** can further include a microphone for receiving audible signals of an end user. The audio system **4212** can also be used for voice recognition applications. The UI **4204** can further include an image sensor **4213** such as a charged coupled device (CCD) camera for capturing still or moving images.

The power supply **4214** can utilize common power management technologies such as replaceable and rechargeable batteries, supply regulation technologies, and/or charging system technologies for supplying energy to the components of the communication device **4200** to facilitate long-range or short-range portable communications. Alternatively, or in combination, the charging system can utilize external power sources such as DC power supplied over a physical interface such as a USB port or other suitable tethering technologies.

The location receiver **4216** can utilize location technology such as a global positioning system (GPS) receiver capable of assisted GPS for identifying a location of the communication device **4200** based on signals generated by a constellation of GPS satellites, which can be used for facilitating location services such as navigation. The motion sensor **4218** can utilize motion sensing technology such as an accelerometer, a gyroscope, or other suitable motion sensing technology to detect motion of the communication device **4200** in three-dimensional space. The orientation sensor **4220** can utilize orientation sensing technology such as a magnetometer to detect the orientation of the communication device **4200** (north, south, west, and east, as well as combined orientations in degrees, minutes, or other suitable orientation metrics).

The communication device **4200** can use the transceiver **4202** to also determine a proximity to a cellular, WiFi, Bluetooth®, or other wireless access points by sensing techniques such as utilizing a received signal strength indicator (RSSI) and/or signal time of arrival (TOA) or time of flight (TOF) measurements. The controller **4206** can utilize computing technologies such as a microprocessor, a digital signal processor (DSP), programmable gate arrays, application specific integrated circuits, and/or a video processor with associated storage memory such as Flash, ROM, RAM, SRAM, DRAM or other storage technologies for executing computer instructions, controlling, and processing data supplied by the aforementioned components of the communication device **4200**.

Other components not shown in FIG. **42** can be used in one or more embodiments of the subject disclosure. For instance, the communication device **4200** can include a slot for adding or removing an identity module such as a Subscriber Identity Module (SIM) card or Universal Integrated Circuit Card (UICC). SIM or UICC cards can be used for identifying subscriber services, executing programs, storing subscriber data, and so on.

In the subject specification, terms such as “store,” “storage,” “data store,” data storage,” “database,” and substantially any other information storage component relevant to operation and functionality of a component, refer to “memory components,” or entities embodied in a “memory”

or components comprising the memory. It will be appreciated that the memory components described herein can be either volatile memory or nonvolatile memory, or can comprise both volatile and nonvolatile memory, by way of illustration, and not limitation, volatile memory, non-volatile memory, disk storage, and memory storage. Further, non-volatile memory can be included in read only memory (ROM), programmable ROM (PROM), electrically programmable ROM (EPROM), electrically erasable ROM (EEPROM), or flash memory. Volatile memory can comprise random access memory (RAM), which acts as external cache memory. By way of illustration and not limitation, RAM is available in many forms such as synchronous RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM), Synchlink DRAM (SLDRAM), and direct Rambus RAM (DRRAM). Additionally, the disclosed memory components of systems or methods herein are intended to comprise, without being limited to comprising, these and any other suitable types of memory.

Moreover, it will be noted that the disclosed subject matter can be practiced with other computer system configurations, comprising single-processor or multiprocessor computer systems, mini-computing devices, mainframe computers, as well as personal computers, hand-held computing devices (e.g., PDA, phone, smartphone, watch, tablet computers, netbook computers, etc.), microprocessor-based or programmable consumer or industrial electronics, and the like. The illustrated aspects can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network; however, some if not all aspects of the subject disclosure can be practiced on stand-alone computers. In a distributed computing environment, program modules can be located in both local and remote memory storage devices.

Some of the embodiments described herein can also employ artificial intelligence (AI) to facilitate automating one or more features described herein. For example, artificial intelligence can be used in optional training controller **230** evaluate and select candidate frequencies, modulation schemes, MIMO modes, and/or guided wave modes in order to maximize transfer efficiency. The embodiments (e.g., in connection with automatically identifying acquired cell sites that provide a maximum value/benefit after addition to an existing communication network) can employ various AI-based schemes for carrying out various embodiments thereof. Moreover, the classifier can be employed to determine a ranking or priority of the each cell site of the acquired network. A classifier is a function that maps an input attribute vector,  $x=(x_1, x_2, x_3, x_4, \dots, x_n)$ , to a confidence that the input belongs to a class, that is,  $f(x)=\text{confidence (class)}$ . Such classification can employ a probabilistic and/or statistical-based analysis (e.g., factoring into the analysis utilities and costs) to prognose or infer an action that a user desires to be automatically performed. A support vector machine (SVM) is an example of a classifier that can be employed. The SVM operates by finding a hypersurface in the space of possible inputs, which the hypersurface attempts to split the triggering criteria from the non-triggering events. Intuitively, this makes the classification correct for testing data that is near, but not identical to training data. Other directed and undirected model classification approaches comprise, e.g., naïve Bayes, Bayesian networks, decision trees, neural networks, fuzzy logic models, and probabilistic classification models providing different pat-

terns of independence can be employed. Classification as used herein also is inclusive of statistical regression that is utilized to develop models of priority.

As will be readily appreciated, one or more of the embodiments can employ classifiers that are explicitly trained (e.g., via a generic training data) as well as implicitly trained (e.g., via observing UE behavior, operator preferences, historical information, receiving extrinsic information). For example, SVMs can be configured via a learning or training phase within a classifier constructor and feature selection module. Thus, the classifier(s) can be used to automatically learn and perform a number of functions, including but not limited to determining according to a predetermined criteria which of the acquired cell sites will benefit a maximum number of subscribers and/or which of the acquired cell sites will add minimum value to the existing communication network coverage, etc.

As used in some contexts in this application, in some embodiments, the terms “component,” “system” and the like are intended to refer to, or comprise, a computer-related entity or an entity related to an operational apparatus with one or more specific functionalities, wherein the entity can be either hardware, a combination of hardware and software, software, or software in execution. As an example, a component may be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, computer-executable instructions, a program, and/or a computer. By way of illustration and not limitation, both an application running on a server and the server can be a component. One or more components may reside within a process and/or thread of execution and a component may be localized on one computer and/or distributed between two or more computers. In addition, these components can execute from various computer readable media having various data structures stored thereon. The components may communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network such as the Internet with other systems via the signal). As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, which is operated by a software or firmware application executed by a processor, wherein the processor can be internal or external to the apparatus and executes at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts, the electronic components can comprise a processor therein to execute software or firmware that confers at least in part the functionality of the electronic components. While various components have been illustrated as separate components, it will be appreciated that multiple components can be implemented as a single component, or a single component can be implemented as multiple components, without departing from example embodiments.

Further, the various embodiments can be implemented as a method, apparatus or article of manufacture using standard programming and/or engineering techniques to produce software, firmware, hardware or any combination thereof to control a computer to implement the disclosed subject matter. The term “article of manufacture” as used herein is intended to encompass a computer program accessible from any computer-readable device or computer-readable storage/communications media. For example, computer readable

storage media can include, but are not limited to, magnetic storage devices (e.g., hard disk, floppy disk, magnetic strips), optical disks (e.g., compact disk (CD), digital versatile disk (DVD)), smart cards, and flash memory devices (e.g., card, stick, key drive). Of course, those skilled in the art will recognize many modifications can be made to this configuration without departing from the scope or spirit of the various embodiments.

In addition, the words “example” and “exemplary” are used herein to mean serving as an instance or illustration. Any embodiment or design described herein as “example” or “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments or designs. Rather, use of the word example or exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form.

Moreover, terms such as “user equipment,” “mobile station,” “mobile,” “subscriber station,” “access terminal,” “terminal,” “handset,” “mobile device” (and/or terms representing similar terminology) can refer to a wireless device utilized by a subscriber or user of a wireless communication service to receive or convey data, control, voice, video, sound, gaming or substantially any data-stream or signaling-stream. The foregoing terms are utilized interchangeably herein and with reference to the related drawings.

Furthermore, the terms “user,” “subscriber,” “customer,” “consumer” and the like are employed interchangeably throughout, unless context warrants particular distinctions among the terms. It should be appreciated that such terms can refer to human entities or automated components supported through artificial intelligence (e.g., a capacity to make inference based, at least, on complex mathematical formalisms), which can provide simulated vision, sound recognition and so forth.

As employed herein, the term “processor” can refer to substantially any computing processing unit or device comprising, but not limited to comprising, single-core processors; single-processors with software multithread execution capability; multi-core processors; multi-core processors with software multithread execution capability; multi-core processors with hardware multithread technology; parallel platforms; and parallel platforms with distributed shared memory. Additionally, a processor can refer to an integrated circuit, an application specific integrated circuit (ASIC), a digital signal processor (DSP), a field programmable gate array (FPGA), a programmable logic controller (PLC), a complex programmable logic device (CPLD), a discrete gate or transistor logic, discrete hardware components or any combination thereof designed to perform the functions described herein. Processors can exploit nano-scale architectures such as, but not limited to, molecular and quantum-dot based transistors, switches and gates, in order to optimize space usage or enhance performance of user equipment. A processor can also be implemented as a combination of computing processing units.

As used herein, terms such as “data storage,” “data storage,” “database,” and substantially any other information

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storage component relevant to operation and functionality of a component, refer to “memory components,” or entities embodied in a “memory” or components comprising the memory. It will be appreciated that the memory components or computer-readable storage media, described herein can be either volatile memory or nonvolatile memory or can include both volatile and nonvolatile memory.

What has been described above includes mere examples of various embodiments. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing these examples, but one of ordinary skill in the art can recognize that many further combinations and permutations of the present embodiments are possible. Accordingly, the embodiments disclosed and/or claimed herein are intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims. Furthermore, to the extent that the term “includes” is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term “comprising” as “comprising” is interpreted when employed as a transitional word in a claim.

In addition, a flow diagram may include a “start” and/or “continue” indication. The “start” and “continue” indications reflect that the steps presented can optionally be incorporated in or otherwise used in conjunction with other routines. In this context, “start” indicates the beginning of the first step presented and may be preceded by other activities not specifically shown. Further, the “continue” indication reflects that the steps presented may be performed multiple times and/or may be succeeded by other activities not specifically shown. Further, while a flow diagram indicates a particular ordering of steps, other orderings are likewise possible provided that the principles of causality are maintained.

As may also be used herein, the term(s) “operably coupled to”, “coupled to”, and/or “coupling” includes direct coupling between items and/or indirect coupling between items via one or more intervening items. Such items and intervening items include, but are not limited to, junctions, communication paths, components, circuit elements, circuits, functional blocks, and/or devices. As an example of indirect coupling, a signal conveyed from a first item to a second item may be modified by one or more intervening items by modifying the form, nature or format of information in a signal, while one or more elements of the information in the signal are nevertheless conveyed in a manner than can be recognized by the second item. In a further example of indirect coupling, an action in a first item can cause a reaction on the second item, as a result of actions and/or reactions in one or more intervening items.

Although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement which achieves the same or similar purpose may be substituted for the embodiments described or shown by the subject disclosure. The subject disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, can be used in the subject disclosure. For instance, one or more features from one or more embodiments can be combined with one or more features of one or more other embodiments. In one or more embodiments, features that are positively recited can also be negatively recited and excluded from the embodiment with or without replacement by another structural and/or functional feature. The steps or functions described with respect to the embodiments of the

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subject disclosure can be performed in any order. The steps or functions described with respect to the embodiments of the subject disclosure can be performed alone or in combination with other steps or functions of the subject disclosure, as well as from other embodiments or from other steps that have not been described in the subject disclosure. Further, more than or less than all of the features described with respect to an embodiment can also be utilized.

What is claimed is:

1. A system comprising:
  - mounting brackets connectable with a distal end of a cross member that is fixably attached to a utility pole;
  - a curved member having a curved shape;
  - clamping brackets connecting the curved member and the mounting brackets; and
  - a mounting carriage connectable with the curved member, wherein the mounting carriage includes an opening for receiving an antenna mount of an antenna, wherein the antenna, when received in the mounting carriage, is suspended beyond the distal end of the cross member.
2. The system of claim 1, wherein the mounting carriage when in an unlocked state slides via a core bearing along the curved member, wherein the mounting carriage when in a locked state does not slide along the curved member, and wherein the clamping brackets connect the curved member and the mounting brackets via threaded lugs.
3. The system of claim 2, wherein the antenna comprises a dielectric antenna, wherein wireless signals are transmitted by electromagnetic waves that propagate without requiring an electrical return path, and wherein the electromagnetic waves are guided by a dielectric core of a cable coupled to a feed point of the dielectric antenna.
4. The system of claim 1, wherein each of the mounting brackets includes an opening to receive one corner of the distal end of the cross member.
5. The system of claim 1, wherein each of the mounting brackets is connectable with the distal end of the cross member via a securing member extending through the mounting bracket and into one corner of the distal end of the cross member.
6. The system of claim 1, wherein each of the mounting brackets includes a dimple adapted to penetrate the cross member at one corner of the distal end of the cross member.
7. The system of claim 1, wherein each of the mounting brackets includes a deformable pad configured to deform and comply with a surface of the distal end of the cross member.
8. The system of claim 1, wherein the antenna mount when in an unlocked state rotates about the opening in the mounting carriage, and wherein the antenna mount when in a locked state does not rotate about the opening in the mounting carriage.
9. A system comprising:
  - mounting brackets connectable with a utility pole;
  - a curved member having a curved shape;
  - clamping brackets connecting the curved member with the mounting brackets; and
  - a mounting carriage connectable with the curved member, wherein the mounting carriage includes an opening for receiving an antenna mount of an antenna, and wherein the mounting carriage includes a core bearing that facilitates the mounting carriage sliding via the core bearing along the curved member when the mounting carriage is in an unlocked state.
10. The system of claim 9, wherein the core bearing has a curved opening therethrough for receiving the curved member.

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11. The system of claim 10, wherein a first radius of curvature of the curved opening of the core bearing equals a second radius of curvature of the curved shape of the curved member.

12. The system of claim 9, wherein each of the mounting brackets includes at least one of a plurality of threaded lugs, and wherein the clamping brackets connect the curved member and the mounting brackets via the plurality of threaded lugs.

13. The system of claim 12, wherein the plurality of threaded lugs are connected to the mounting brackets via a pivotal connection.

14. The system of claim 9, further comprising an inter-bracket plate connected with a pair of the mounting brackets, wherein the inter-bracket plate connects an electronics module thereto, and wherein the electronics module enables wireless communications via the antenna.

15. The system of claim 9, wherein the mounting brackets each include a slot for receiving an adjustable strap that facilitates installation of the mounting brackets to the utility pole.

16. The system of claim 9, wherein the mounting brackets each include an inner face with a non-linear shape that is configured for positioning against the utility pole.

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17. The system of claim 16, wherein the inner face of each of the mounting brackets includes deformable contact pads.

18. A method comprising:  
connecting mounting brackets to a utility pole;  
connecting a mounting carriage to a curved member;  
sliding the mounting carriage to a particular position along the curved member via a core bearing of the mounting carriage;  
connecting the curved member to a first mounting bracket and a second mounting bracket of the mounting brackets; and  
connecting an antenna to the mounting carriage.

19. The method of claim 18, further comprising:  
connecting an inter-bracket plate with a pair of the mounting brackets; and  
connecting an electronics module with the inter-bracket plate, wherein the electronics module enables wireless communications via the antenna.

20. The method of claim 18, wherein the connecting the curved member to the first and second mounting brackets is via clamping brackets of the curved member that engage with threaded lugs of the mounting brackets, wherein the threaded lugs are pivotally connected to the mounting brackets.

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